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NOVEMBER 1925

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, New York, N. Y., February 8-11, 1926

MEETINGS OF OTHER SOCIETIES

The American Society of Mechanical Engineers, Annual Meeting, New York, N. Y., November 30th-December 4

National Research Council, Engineering Division, Fifth Annual Meeting, Washington, D. C., December 3-4

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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Cooperation Between Scientists and Engineers

American scientists and engineers feel and have for a long time felt the need of closer contacts and cooperation. The American Association for the Advancement of Science was intended from its very beginning to establish these contacts. It is one of the oldest scientific associations in this country; considerably older than any one of our engineering societies. During its early history it was the only scientific association in which scientists and engineers met and discussed the problems of pure and applied science. Since the organization of the engineering societies engineers began to devote a more and more exclusive attention to these specialized organizations and less to the national society which is devoted to the general interests of science. In order to counteract this perfectly natural tendency, an engineering section was established in the American Association for the Advancement of Science. Through the members of this section the voice of the engineers was heard and attentively listened to at the annual meetings of the Association. These annual meetings offer a splendid opportunity to the scientists and the engineers to address themselves to the American nation on subjects of science and engineering which are of immediate interest to our nation. Our nation recognizes that the American Association is a truly national organization; that explains why among its membership there are many who are not professional scientists or engineers. Their membership is due to their general interest in American science. In this respect the American Association for the Advancement of Science resembles very much the British Association for the Advancement of Science. There is, however, one significant difference between them. The British Association, it is believed, receives a more enthusiastic support from the British engineers than the American Association receives from the American engineers. This belief is encouraged by the fact that the British scientific weekly, *Nature*, is more widely read among British engineers than the American scientific weekly, *Science*, is read among American engineers. These two scientific periodicals are devoted to the general interests of science in a similar manner as the two national associations, the American and the British Association, are devoted to them. From that point of view we may say that the two periodicals are the mouthpieces of these two Associations. The fact that *Nature* is superior to *Science* is generally admitted. Let us also admit for the sake of argument that the average quality of the scientific men who contribute to *Nature* is superior to the average quality of the scientific men who contribute to *Science*. This admission will not entirely explain the superiority of *Nature* to *Science*. There must be another cause for this superiority. Those who have studied this subject carefully are inclined to think that the interest of the American engineer in *Science* is not as lively as that of British engineer is in *Nature*. Hence *Nature* has a much larger number of subscribers than *Science* has, and, other things being equal, the periodical with the larger number of subscribers will be superior to that having the smaller number of subscribers.

A short time ago several presidents and secretaries of the national engineering societies and prominent members of these societies met at a luncheon for the purpose of discussing ways and means of stimulating the interest of the American engineer in the general aspect of science. There was a unanimity of opinion that this matter deserves a serious attention of the national engineering societies, and that the most direct method of doing this is to encourage a closer connection and active cooperation between the national engineering societies and the American Association for the Advancement of Science. One of the immediate effects of this achievement would be the raising to a higher level of *Science*, the mouthpiece of the American Association for the Advancement of Science. There is a crying need for a scientific periodical which in its form as well as in its substance will be a worthy mouthpiece of American science and engineering. We must aim to make it as good as *Nature*, the British scientific periodical which is devoted, primarily, to the general interests of British science.

M. I. Pupin

Some Leaders of the A. I. E. E.

Henry Gordon Stott, the twentieth president of the Institute, was born in the year 1866, in the Orkney Islands, Scotland. His early education was gained at Watson Collegiate, Edinburgh; the College of Science and Arts, Glasgow, and the Glasgow and University of Scotland Technical College.

When but eighteen years of age Mr. Stott entered the service of an early electric light company in Glasgow, later transferring his services to a submarine telegraph cable company in the capacity of research and development engineer. In the year 1889, he was appointed assistant engineer of the Brush Electrical Engineering Company's electric light plant at Bournemouth, Eng-

land; going to Madrid, Spain, a year later, in charge of electric light undertakings.

In the year 1891, Mr. Stott came to the United States and entered the service of the Buffalo, N. Y. General Electric Company, where he continued until the year 1901. During these ten years he carried out many important electrical installation projects. In 1901 he accepted the position of superintendent of motive power, of the Interborough Rapid Transit Company, New York City, continuing in the service of that company and of the New York Railways Company until the time of his death in 1917. Mr. Stott was president of the A. I. E. E. during the term 1907-8. He was a member of many scientific and technical societies, and was the author of many published papers dealing with various important electrical subjects.

A. I. E. E. Life Membership

The attention of the membership of the Institute is called to the opportunity to obtain Life Membership in accordance with the provisions embodied in an amendment to the constitution adopted by the membership in May 1925. Life Membership may be obtained by a member of any grade, by the payment of a single sum based upon the annuity rates of life insurance companies, and depending upon the age of the member concerned and the annual dues of his grade of membership.

The amount of the single payment to be made is definitely stated in the Section 20 of the by-laws, for all ages and all grades of membership. Following are examples:

Age Last Birthday	*Associates and Members (Dues $15 per year)	Fellows (Dues $20 per year)
21	$307.49	..
25	298.56	..
30	285.81	..
35	271.14	$361.52
40	254.54	339.38
45	236.09	314.78
50	215.94	287.92
60	172.17	229.56
70	127.79	170.38

*From the amounts indicated certain deductions will be made for Associates during the first six years of membership in that grade, based upon dues of $10 for the first six years and $15 thereafter.

All amounts paid in for Life Memberships are now placed in a special fund so administered as to maintain a proper reserve at the beginning of each fiscal year corresponding to the annuity values for all surviving members at their then attained age, the excess above the required reserve being transferred to the general fund of the Institute each year in lieu of the payment of annual dues by Life Members.

The principal object of Life Membership is to provide continuity of association with the Institute and its activities during the future, and possibly less productive, years.

More complete information, including the exact amount required to obtain Life Membership by any individual member, will be mailed upon application to Institute headquarters, New York.

F. L. Hutchinson,
National Secretary.

Nineteen years of the I. E. S.

Looking backward over the nineteen years of existence of the Illuminating Engineering Society, a perspective embracing various phases of interest is obtained. In the earlier years, the papers presented before the society were largely confined to the theoretical considerations. Out of this early period there developed an appreciation of the extent to which lighting is influential in the world's activities. Now this is bearing fruit in the form of many papers of great practical interest. Moreover, as lighting men have, themselves, become convinced of the great part that lighting can perform in the world's work and in human happiness, the desire to educate the consumer has greatly increased. It is not surprising, therefore, that at the Detroit convention of the Illuminating Engineering Society, there was much interest evidenced in educational movements and in papers and demonstrations prepared from the practical points of view.

The lighting specialists of central-station companies contributed an interesting session, showing the increasing effort toward better lighting that is being directed by such organizations. In this particular session, industrial and purely commercial lighting were chiefly discussed, and virtually nothing was said of the great commercial possibilities of residence lighting. Interest in the industrial lighting campaign which is now under way was made evident by various papers and discussions. A number of fundamental and practical papers on lighting for work places provided much of value.

Automobile headlighting and traffic-control systems came in for their share of attention. Street lighting was well represented on the program. These discussions reflected the importance of lighting on the streets and highways. Another session, lasting half a day, was devoted to daylighting and to the mixture of artificial and natural light. In fact, the variety of foundational scientific papers indicates that the society is in a healthy condition and that it is performing a function for which it is peculiarly adapted. That is, it is a forum, quite free from commercial bias, for the presentation of papers and discussions pertaining to the production, measurement and utilization of light. All in all, it may be said that utilization received by far the most attention. This is the natural consequence of the progress in knowledge of light and lighting. In the papers presented the central-station companies are provided with much data for the foundation of lighting revenue.—*Electrical World.*

Sleet and Ice Troubles on Transmission Lines in New England

C. R. OLIVER[1]
Associate, A. I. E. E.

Synopsis.—*This paper deals with the troubles one of the large power companies in New England has encountered from sleet and ice on transmission lines. The experience of this company should bring home to the transmission line designer the fact that in certain parts of the country sleet is a very serious problem and should be taken into account in designing all new transmission lines. It also shows the necessity for looking over the existing transmission systems with a view to providing some quick and easy method of thawing sleet from the lines already constructed.*

* * * * *

UNTIL recent years, New England was not thought of as a section of country particularly susceptible to sleet; in fact, no serious trouble had been experienced by any of the communication or power companies before the storms of recent years, and outside of the usual one-half inches of ice and 8-lb. wind pressure, no particular attention was given by the designing engineer to the possibility of trouble from this source, either in the tower or in the conductor. Our recent experience has convinced us that there is no single tower line in New England built before 1922 that would stand up under the excessive loads that they may be called upon to carry. The only reason that any of them are standing today is that they have been fortunate enough to escape the sleet.

The New England Company Power System

In describing the sleet troubles, the author will confine himself to those experienced by the New England Company Power System lines, with which he is most familiar.

This system, with its connections, extends from the New York State line across the State of Massachusetts to Boston, down into Rhode Island to Providence, and across to Fall River. In the northern section it extends half-way through Vermont, into New Hampshire and across the State of Connecticut to New London and Stafford Springs. Its main trunk lines are towers built in 1908 to 1914. Within recent years wooden pole lines have been constructed instead of tower lines. All of these lines operate at 66,000 volts. Last year a new double-circuit tower line was completed, 75 miles long across the center of Massachusetts, designed to operate at 110,000 volts. There are 240 miles of 66,000-volt, double-circuit tower line; 70 miles of 66,000-volt, double-circuit pole line; 275 miles of 66,000-volt, single-circuit, pole line; 75 miles of 110,000-volt, double-circuit, tower line, and approximately 75 miles of 22,000- and 13,000-volt feeder lines.

Trouble of 1916

The first serious trouble on the system, due to sleet, came on December 22, 1916, on the tower line that connects the station near Hoosac Tunnel, Massachusetts, with the substation at North Adams, Massachusetts. This line was built in 1913, and consists entirely of 75-ft. standard square towers weighing approximately 5000 lb. each, with two circuits of No. 1 copper conductor, each circuit being arranged in a vertical plane, and with a ground wire at the peak of the towers. It is only 8.3 miles long, but in this length it crosses a section of country varying in elevation from 1000 to 2300 ft. above sea level. During the first winter of service on this line it was observed that quite frequently a slight sleet formation took place on the wires, and the engineers of the company thought that the No. 1 copper was too light to carry the sleet load. In the following summer, the No. 1 copper on five towers over the highest peak was replaced with $\frac{3}{8}$-in. crucible steel conductors, and all of the towers over this peak were dead-ended.

This decision was very unwise, for two years later, in 1916, this section of the country was visited by a very heavy sleet storm, and ice of three to four inch diameter was sticking to the wires. All five of these towers on which the heavier conductors had been installed were completely wrecked. This failure occurred without a single break in the conductor, showing conclusively that had the towers been designed for the stronger conductor, no interruption would have occurred.

Only temporary repairs could be made, using low wooden structures, as the whole mountain side was frozen and covered with glare ice. Later, in the summer, the wooden structures were replaced with ten low towers, placing all wires in a horizontal plane. These towers were designed to withstand the sleet and wind loads for this section, and since their installation no trouble in this particular section has been experienced, although there have been some very heavy sleet storms on this line.

Fig. 1 shows the replacement towers which have been very satisfactory.

Trouble of November, 1920

During Thanksgiving week of 1920 another sleet storm swept over this line, affecting a four mile section varying in elevation from 1500 to 2300 ft. The sleet was

1. Assistant General Manager, New England Power Co., Worcester, Mass.

Presented at the Regional Meeting of the A. I. E. E., Swampscott, Mass., May 7, 1925.

again three and one-half in. to four in. thick, and although there was no tower failure, there were many span-wires broken; so many in fact, that later in the summer this whole section had to be resagged. The storm lasted five days and no headway could be made toward getting the line back into service, for as fast as breaks were repaired in one section trouble would develop in other spans. In desperation some 2300/220-volt transformers were borrowed from one of the manufacturers and, by a temporary connection, were so arranged that it was possible to secure approximately 6000 volts;

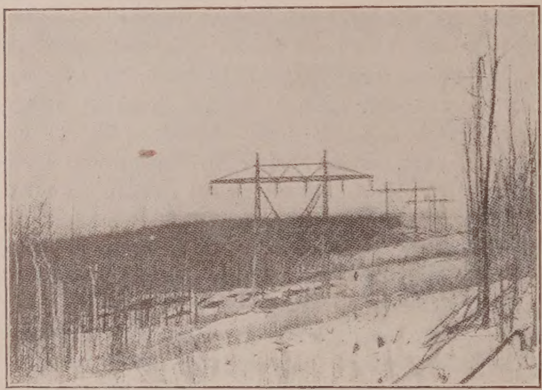


Fig. 1—A Section of the Line Showing Type of Replacement Towers

and with this pressure, using about 300 amperes, the sleet was cleared from the line by heat. During all this time the customers supplied from the North Adams substation were without power.

After the storm a careful examination of the line showed no signs of any of the towers being overstressed, nor were the wires stretched beyond their elastic limit. The only apparent damage was the broken conductors due to the overloading of the ice.

Fig. 2 shows the profile of the line from Hoosac Tunnel station to Adams substation, and the extent of ice trouble is indicated by the shaded part of the line.

Trouble in 1921

The most disastrous sleet storm on record in this section of the country started December 28, 1921. There was a steady, drizzling rain for three days with a temperature of around 32 deg. fahr. This froze as soon as it struck, thus accumulating ice three and four inches in diameter on wires, towers and trees. There was also a wind of about thirty miles an hour accompanying this storm, which appeared to have three distinct paths; one across the mountains between Shelbourne Falls and North Adams, one in the hills between Leverett and Ware, and one from Gardner east to the coast, the storm being heaviest within a 30-mi. radius of the city of Worcester, Massachusetts. Down the Connecticut Valley and in other sections of the system there was snow and very little damage to power and lines of communication. On the mountains around Hoosac Tunnel, where for years there had been so much trouble from sleet, the ice was just as heavy as in previous years but during this whole time service was maintained on two circuits 66,000-volt tower line without interruption. This was due entirely to the sleet-thawing method previously worked out. The telephone trunk-line over this mountain had, in early years, successfully withstood the sleet but was now completely wiped out. Lines affected in the company system were as follows:

1. Over 55 miles of double-circuit, 2/0 copper on 75-ft., square towers, weighing approximately 5000 lb. each, with the wires in a vertical plane and the ground wire at the peak: This line was built in 1913-1914 and extends from Shelbourne Falls to Millbury and Pawtucket. There were 69 tower failures, five towers with broken peaks and four with damaged crossarms. The tower failures consisted of broken masts, crippled legs, broken crossarms, damaged footings, both in tension and compression, and quite a few towers were completely wrecked.

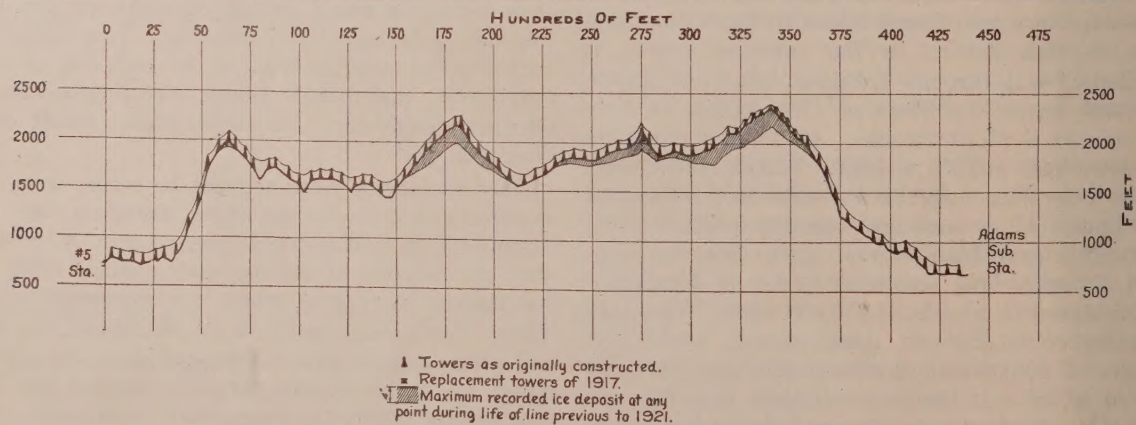


Fig. 2—Profile of Nos. 9-10 Lines from No. 5 Station to Adams Substation

Approximately 75 per cent of the damage was at

dead-end points, and in addition to the tower failures, there were many hundreds of broken spans on both power and ground wires.

Temporary repairs were made by building a 66,000-volt, single-circuit pole line along the edge of the right of way, and later, the good parts of the damaged towers were salvaged, the towers being replaced with new material purchased.

2. Over 40 miles of double-circuit, No. 2/0 and No. 2 copper line, with bayonet type towers, 50 ft. high, with pins, insulators and wires arranged in a triangular position: This line was constructed in 1908 and extends from Vernon, Vermont, to Worcester, Massachusetts, and all towers had been designed to break the conductor. Only three towers failed on this line, two being at angle points of over 45 deg., and the third tower was pulled down by the failure of the other two. Between Worcester and Gardner there were many hundreds of broken spans, and damaged insulators and pins.

Fig. 3—Enclosures Show Sections Most Seriously Affected by Sleet

3. Over ten miles of "A" frame, double-circuit tower line with No. 2 copper in a vertical plane and ½-in., copper-clad ground wire at the peak of the tower: This line passes around the city of Worcester on a very crooked right of way, with many large angles. Among the "A" frames were mixed a few 75-ft., square towers at heavy angles and guyed to take the expected loading. Due to the excessive sleet loading, however, some of the angle towers gave way and 78 towers were completely wrecked. On the remaining towers quite a few span wires were broken and the whole line was so completely wrecked that it was necessary to replace all of the damaged towers with two-pole structures.

4. Over 50 miles of wooden pole line with wishbone crossarms and suspension insulators: These poles were substantially guyed and double-pole construction used on all dead-end points. Four or five crossarms were broken and quite a few poles were thrown out of the line, but there were no broken poles; there were also a few broken conductor spans of No. 2 copper, but it was a comparatively easy job to put these pole lines back in service.

5. In addition to the high-tension trouble, there were many miles of 13,000- and 22,000- volt feeder lines running along city streets carrying No. 2/0 copper and smaller. There were many broken span wires, but this was caused primarily by the trees, overloaded with ice, falling on the feeder lines and carrying them down. There was very little pole damage, and these lines were quickly put back into service as soon as the sleet was cleared.

Fig. 3 shows the area most affected by sleet during this storm.

Troubles of March, 1924

On the 11th of March, 1924, during a heavy snowstorm, the system began to experience trouble in the southern section, centering around Worcester and Providence. The wet snow packed around the insulators and stuck to the wires. By night it became so serious that Millbury, (Mass.), and Woonsocket and Warren, (R. I.) substations were completely isolated from the system. The storm centered in Rhode Island, and its effect on the balance of the system around Worcester was not so serious.

The trouble was caused by the very wet snow, sticking to the wires and towers, becoming solidified due to a drop in the temperature and this combination of snow load and a 60-mile wind completed the damage. In Rhode Island, snow accumulated to a diameter of four inches and actual measurements showed that it weighed 48 lb. per cubic foot. Around Worcester the snow was not so wet, and although the snowfall there was greater, the accumulation on the wires was much less. On lines north of Worcester there were very few broken spans on any of the circuits, and these circuits were all back in condition within a short while.

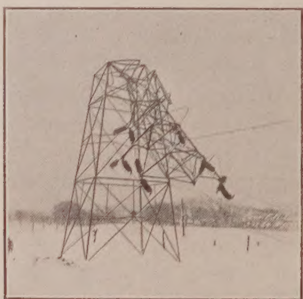
Between Worcester and Pawtucket, R. I., a distance of thirty miles, there were 36 broken span wires, 21 of them occuring in the last ten miles; but there was no structure damage. All of the towers in this section were standard 75-ft. square towers, weighing approximately 5000 lb., with the wires in a vertical plane.

The heaviest damage centered around Providence and on the transmission line to Fall River, (16.5 miles), 94 out of a total of 147 towers were damaged. This damage varied from broken masts to completely wrecked structures. The line consisted of 75-ft. standard square towers with the wires in the vertical plane and weighing about 3500 lb. Being lighter than the other 75-ft. towers on the system, the effect of the storm on these was much more disastrous. Temporary repairs were made by building a double-circuit, wooden-pole line along the edge of the right of way.

Figs. 4 and 5 show typical tower failures, illustrating how completely the towers were wrecked, and Fig. 6

is a photo of solidified snow on the wire, four inches in diameter.

An interesting thing developed during this storm; a 66,000-volt, double-pole, double circuit of No. 2/0 copper, wooden pole line with all wires in a horizontal plane runs around the north side of Pawtucket to East Providence. This pole line for quite a distance is on an adjacent right of way with a standard 75-ft. tower line. The ten miles of wooden pole line came through the storm with only three broken conductors and a few unhooked insulator strings, while the tower line had several towers completely wrecked and a great many broken span wires. One of these towers, due to the heavy load of ice, fell across the pole line and caused one of the above mentioned broken spans. The pole line had no broken or damaged structures and was put back in condition in one day's time.



Figs. 4-5—Tower Failures

Fig. 7 is a photograph of the 75-ft. tower which, in falling, put the wooden pole line out of service.

Sleet Thawing

The first experience of sleet thawing on the company's system was during the storm of 1920. The lines were cleared of ice in western Massachusetts by using a group of 2300/220-volt transformers connected in series and paralleled, to secure from 6000 to 8000 volts at 300 amperes. This was only a temporary connection made up after six days of ineffective work trying to clear the lines, and much to the surprise of all it worked amazingly well. These were retained in the plant during the remainder of the winter. Plans were then made to provide the Hoosac Tunnel Station with permanent means of thawing the ice from the two No. 1 copper lines running over the mountain to North Adams, eight miles, and the two No. 1 circuits running over the mountains to Shelbourne Falls,—14 miles. Equipment in this station consisted of two 11,000-volt, 25-cycle generators, and two 2300-volt, 60-cycle generators; five 3000-kv-a., three-phase, 66,000- to 2300-volt transformers.

From many tests made in the field, it was evident

Fig. 6—Solidified-Snow-Covered Cable

that from 250 to 300 amperes at 6600 to 8000 volts would be required to clear in an hour the No. 1 copper of sleet. The engineers of the company were in favor of providing a separate auto-transformer for this service only, but on receiving the proposal from the manufacturers, the proposition was abandoned as too excessive in cost. Further study was made and it was finally discovered that by opening the delta on the low-tension side of one of the three-phase transformers and connecting the individual coils in series with the delta of a second three-phase transformer and

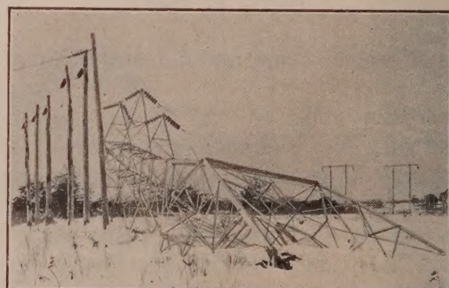


Fig. 7—Destruction of Wooden Pole Line by Fall of 75-Ft. Tower

with the two high-tension sides connected in multiple, an extended delta could be secured, giving the desired voltage.

Fig. 8 shows the diagram of connection and the method of connecting the two deltas.

In order to make use of this combination for sleet thawing and still keep the transformers available for ordinary service during the other times of the year, all six secondary leads were brought out of one of the

three-phase transformers to disconnecting switches mounted on the ceiling overhead the unit. These switches were so arranged that the special combination for thawing could be made very quickly, and special cables were run from the extended delta up to the roof of the building, where a flexible connection of a hundred feet of three-phase cable was provided, by means of which connections could be made to any of the four lines on the roof to be thawed. The total apparatus tied up for sleet thawing consisted of one 60-cycle,

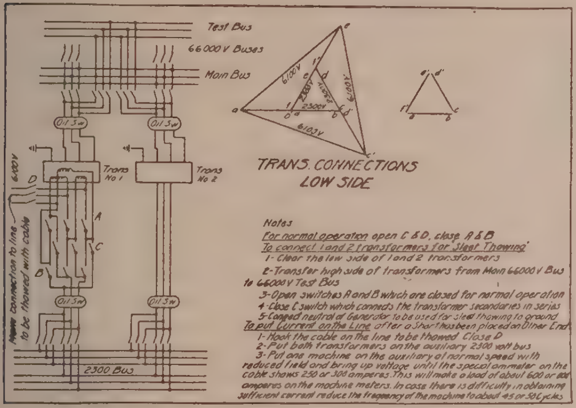


FIG. 8

2300-volt generator, and two three-phase transformers. This equipment, with a separate exciter, could be operated independent of the balance of the equipment in the station. The total cost of the sleet thawing outfit was, therefore, very moderate, and the only new equipment required was a few sets of 6600-volt, disconnecting switches and some cables. A test made under actual operating condition on the line to North Adams, (8.3 miles long and of No. 1 copper), showed the following result at 60 cycles.

Line Amperes	Generator Volts	Line Volts
200	1170	3150
250	1460	3930
300	1740	4760
390	2300	6150

A test on the line to Shelbourne Falls, (14.7 miles and of No. 1 copper), showed the following results:

Line Amperes	60 Cycle Generator Volts	Line Volts
200	2290	5600
250	2600	6970
	40 Cycle	
200	1670	4470
250	2090	5590
275	2300	6120
300	2500	6700

Within the last year, the third 25-cycle, 11,000-volt generator has been installed, and this will also be available for sleet thawing.

The success of the sleet-thawing arrangement depends entirely upon complete cooperation between the generating station at Hoosac Tunnel and the stations at the end of the line to be thawed. This cooperation normally requires telephone connection between the stations, but during sleet trouble, the telephone lines are usually the first ones to be put out of commission, so it was necessary to devise a means of working the sleet thawing device absolutely independent of telephone. Accordingly, a definite schedule was worked out for 24 hours, whereby sleet could be thawed on any or all of the four lines radiating from this station. This schedule is independent of dispatchers' orders or telephone, and it functions even when all telephone connections have been completely wiped out.

The sleet thawing is always started and carried on in accordance with this schedule regardless of the time of day and the number of lines to be thawed, so that the crews at both ends of the lines are thoroughly familiar with the routine of operation. A complete cycle of the schedule is given as follows:

Time	Shel. Falls Sta.	Hoosac Tunnel Station	North Adams Substa.
2:45 p.m.	Remove short from No. 7 Line	Start heat on No. 10 Line	..
3:00 p.m.	Close No. 7 Line when alive	Energize No. 7 Line at 66,000 volts	..
3:15 p.m.	Open and switch No. 8 Line	Open and switch No. 8 Line	..
3:30 p.m.	Attach short to No. 8 Line if dead	Stop heat on No. 10 Line	..
3:45 p.m.	..	Start heat on No. 8 Line	Remove short from No. 10 Line
4:00 p.m.	..	Energize No. 10 Line at 66,000 volts	Close No. 10 switch when alive
4:30 p.m.	..	Open and switch No. 9 Line	Open and switch No. 9 Line
4:45 p.m.	..	Stop heat on No. 8 Line	Attach short on No. 9 Line if dead
5:00 p.m.	Remove short from No. 8 Line	Start heat on No. 9 Line	..
5:15 p.m.	Close No. 8 Line switch when alive	Energize No. 8 Line at 66,000 volts	..
5:30 p.m.	Open and switch No. 7 Line	Open and switch No. 7 Line	..
5:45 p.m.	Attach short to No. 7 Line if dead	Stop heat on No. 9	...
6:00 p.m.	..	Start heat on No. 7 Line	Remove short from No. 9 Line
6:15 p.m.	..	Energize No. 9 Line at 66,000 volts	Close No. 9 Line switch when alive
6:45 p.m.	..	Open and switch No. 10 Line	Open and switch No. 10 Line
7:00 p.m.	..	Stop heat on No. 7 Line	Attach short on No. 10 Line if dead
7:15 p.m.	Remove short from No. 7 Line	Start heat on No. 10 Line	..
7:30 p.m.	Close No. 7 Line switch when alive	Energize No. 7 Line at 66,000 volts	..

The sleet thawing equipment was completed several weeks before the storm of 1921, but the crews at the station had not become proficient in its use, and when the sleet storm struck, it was not deemed wise to attempt to keep all four lines free from ice. All energy was devoted to keeping the lines over Florida Mountain

clear. As a result, these two lines came through the storm with a clean record and service was maintained to the customer during the whole time, in spite of the fact that all other communications and telephone lines in this part of the country were very seriously affected by the storm. This test thoroughly convinced the organization of the efficiency of the device, and since that time, sleet-thawing devices have been installed in several other points on the system.

Conclusions

The lessons learned during the past few years have been very expensive, but it is hoped that the future will benefit by so designing the lines of the system that they will come through a storm with a clean record. The following facts have been discovered:

1. That towers should be designed to stand regardless of the load on the conductors. A conductor failure is bad, but a structure failure is positively disastrous.

2. That earth footings fail very often in compression and this failure has wrecked many towers. There are also some failures of footings in tension.

3. That guying towers at angle points instead of using a heavy structure is very poor makeshift. The tower usually fails before the guy has a chance to do any work.

4. That "A" frame towers are not an ideal combination for sleet conditions even when all points are reinforced with heavy square towers installed every half mile in tangent and with a heavy ground wire overhead.

5. That vertical spacing of conductors will never prove satisfactory for sleet condition, not even with the middle crossarm extended.

6. That the so-called 75-ft. standard square towers as used in this section of the country for years will not withstand the sleet and wind load.

7. That wooden pole lines have suffered less damage and are easier to put back into service than light tower lines.

8. That in building important high-tension lines there is no half-way ground. To withstand the sleet it should be either a double-pole construction with steel crossarms or a steel tower with suitable factors of safety and with all wires in a horizontal plane.

9. That wherever possible it is advisable to install a thawing device if it can be done at a reasonable figure. This is a very desirable addition in New England, and will pay for itself many times on transmission lines thus protected from the sleet storm.

10. That over 60 per cent of trouble occurs at dead-end towers. These should be self supporting and not guyed, and as many angles as possible eliminated.

It is quite evident that ideas have had to be revised about transmission line design for this section of the country. During the past two years, the Company has constructed over 125 miles of 110,000-volt transmission lines and these lines have been designed with the thought that it was possible to build one that would withstand even the severe sleet storms of New England. Advantage has been taken of the lesson we have learned from the other sleet storms, and it is believed that the present transmission line will prove satisfactory.

Discussion

SLEET AND ICE ON TRANSMISSION LINES

(Swampscott, Mass., May 7, 1925)

L. W. W. Morrow: The Pennsylvania Power & Light System, as well as other companies in central Pennsylvania, have encountered this sleet problem for several years, and have introduced a method of combating sleet which I think will prove of interest. It is somewhat along the same lines as the method used by the New England Power Company.

The method is based on the premise of catching sleet before it forms. In other words, we all know that it takes a large amount of heat to melt ice once formed. Down there most of their sleet occurs only in the high-altitude territory, so they have organized a system whereby, after studying all weather maps and close observation of approaching storms, all patrolmen are concentrated into the sleet areas to be on the job to start immediately if there is any chance whatsoever of sleet forming on any line.

If a report comes in that a sleet storm is approaching, they immediately organize to combat the sleet. This is done by isolating generators in stations sectionalizing lines as much as possible, improvising equipment that can short-circuit any line, and attempting to heat the lines before the sleet forms. It doesn't take much heat in a line to keep sleet from forming, but it takes an immense amount of heat to melt ice off the line once it is formed. So their method is sectionalization and crowding loads into lines, utilizing generators in stations, putting energy into the lines they are trying to warm to keep sleet from forming. It is a scheduled proposition, definitely arranged, with all men on the whole system alert to prevent sleet from damaging the system.

The result of their experience has been that in the last year or two they have had very little trouble and have been able to combat sleet very successfully.

J. Roubicek: I think it interesting to see how the sleet melting is effected in one of the recent additions to the New England Power Systems. I am referring to the Montauk plant in Fall River.

There is a 32,000-kw. generator operating on a bank of transformers temporarily connected to give 66,000 volts on the high-tension side. The generator cables are led to a small cable house in the outdoor switchyard, from which point bare copper connections are made to the transformer. A double-throw, disconnecting switch is located in the top of the cable house, by means of which it is possible to throw the generator output either on the transformer bank, or directly on the outgoing high-tension line, (hereby bridging switches, transformers and high-tension apparatus in the outdoor switchyard), and subject the high-tension lines to the passage of the heavy generator current. Lamps in the cable house indicate whether the transformer oil switches are closed or opened, so that the operator can make no mistakes in interrupting the transformer circuit while the breakers are in. The connection of the 14,000-volt sleet-melting cable to the high-tension line is made by solderless connectors which are disconnected when not in use.

H. S. Knowlton: The cost of modern transmission lines for high-voltage service is rapidly approaching a figure per mile

comparable with the cost of building steam railroads perhaps a generation ago, and it is certainly pretty nearly one-fourth of the cost of building steam railroads per mile through some of the canyons of the Far West. I think it would be very interesting if Mr. Oliver would say just a few words about what range of costs per mile have been encountered in his practise.

R. E. Argersinger: Some twelve years ago, before much trouble of sleet on transmission lines had been experienced in New England the company with which I am connected built a transmission line in Connecticut. This was a two-circuit line with No. 2 copper wires, each circuit in a vertical plane on one side of the tower.

Considerable sleet trouble was experienced, but a large portion of it was eliminated by extending the middle cross arm. However, it was later decided to attempt to melt the sleet from the wires and this was done successfully over a length of line approximating 20 mi., by short-circuiting one end of the circuit and applying voltage at the other end. A current of 175 amperes will melt sleet on these No. 2 wires with the air at about 32 deg. fahr. However, if there is a breeze and the temperature gets down to 20 deg. fahr., it will take nearly 300 amperes to obtain satisfactory results.

I did not clearly understand from Mr. Oliver the size of wire in the case to which he referred.

C. R. Oliver: It is our experience that 300 amperes will thaw the sleet if it is taken in time. The size of which I was speaking is No. 1.

R. E. Argersinger: If you start as soon as sleet begins to form, considerably less current is required to prevent further sleet formation than would be necessary to free the wire from a considerable thickness of sleet after definite formation.

I believe that in view of sleet troubles which have occurred in New England in recent years, more attention should be paid to the design of the line towers. In too many cases towers are purchased without sufficient attention to stresses allowed in the design and the compression formula employed; also to the proper factor of safety.

Last winter St. Louis experienced a very severe sleet storm and a great deal of damage was done throughout the district to overhead work. As reported to us the Keokuk-St. Louis steel tower line "stood like a rock,"—the result of careful structural analysis in the design and an ample factor of safety.

J. A. Johnson: Some years ago I had occasion to design a transmission line and carried out that old practise of going into the market and buying a standard product from a manufacturer. During the construction of the line, a heavy sleet storm occurred and several towers were wrecked before the line was ever put in service. The point I wish to bring out is that this sleet-thawing device ought to be the first thing provided when building a transmission line, and one should not wait until the line has been built and in service several months before beginning to think of sleet protection.

C. R. Oliver: It has been our experience that in the two or three hours between the time we stop thawing a line and get back to it, the sleet forms a little but not seriously. The whole trick that we have learned in sleet thawing is to get at it quickly. With very light sleet we have no trouble, but once the sleet gets two inches thick, you have real trouble on your hands, because your conductors sag down in the old vertical spacing and one span will unload before the other span does and you have a burned-off conductor results. We try to get to thawing the minute we find there is any sleet.

It has been true that there has not been as much thought put into the transmission-line tower design as we have put into our substation design or power house design.

We build a substation structure, and the structural engineer will calculate every member in that structure and all the stresses, and then add one hundred per cent in order to play safe. And by the time he gets through he adds another hundred per cent. We don't put that factor of safety into transmission lines; at least we haven't in the past. Very few men can actually calculate stresses in the mast of the tower, particularly in the old type of tower. A footing designed with delightful intention very often crumbles in compression, and if just one member crumbles in a particular footing you have a damaged tower results.

On the line that we finished just last year, we tried to put as much thought into the building of these individual towers as we did into the building of a structure of any kind. When the footings were excavated an engineer was there with a transit, and he stayed with the footing crew the whole time, and that footing was set just as carefully and just as much to grade as if we were setting the footing of a building.

Regarding the question of single-pole construction, this has been a standard on our system now for about six years; that is, up to angles of 15 deg. we use a so-called double-pole construction with a single cross arm, but over angles of 15 deg., we take an individual pole and dead-end of the wire with a pull-off construction for each phase.

Regarding the Moloney-type footing, we haven't used any of these. We know nothing about them except what some of our friends who have tested them have told us, but we hope to try some of them out in test if not in actual use.

Mr. Knowlton asked about the cost of transmission lines. Well, that depends much on the designing engineer, the type of country you are going through, the type of service you have to give. There are many indeterminate figures in the problem. We can give you what a 110,000-volt line costs, but it is dangerous to use it on any other section of the country; in fact, it is dangerous to use it in any way except as a guide.

We had that illustrated some time ago with one of our financial men. We were talking to some of the Southern fellows about building transmission lines, and had just put in an estimate of \$15,000 a mile. He said, "We build that kind of lines for \$8000 a mile," and we have had a very difficult time explaining to our people why we can't build them for \$8000 a mile. But it is due to the character of the country, to the loadings we get, to the care we try to put into the lines, and it makes your cost go up. We have seen some recent estimates of 220,000 volt, running about \$40,000 a mile for double circuit. On the 110,000, so-called flat construction with six wires in one plane, we run about \$25,000 a mile, including the right of way and the fees.

Mr. Morrow spoke about sleet-thawing down in Pennsylvania. They have an ideal condition with their load at one point and power station at another part of the system, and can bunch their load therefore on one line. But we have a condition in New England quite different from that, that is, we have a 66,000-volt distribution system in effect, and there is no way that we can bunch the load over one line and keep the sleet off.

PLANES SURVEY POWER SITES WITH CAMERAS

Just as airplanes equipped with special cameras were used during the World War to learn of conditions along front line trenches and in No Man's Land, they are now being employed in preliminary surveys of areas where hydroelectric developments are under consideration.

Not long ago the Green River Basin in the North Carolina Blue Ridge Mountains covering an area of 55 square miles was surveyed in this manner. The mountains and forest meant little to the airplane used and the work was completed much sooner than would have been the case if ordinary surveying methods had been used.

Latest Design and Practise in Power Plants

By Committee on Power Generation*

Introduction

PROGRESS in the art of steam station design and operation has been so rapid as to rather bewilder even the men who are giving their whole time and thought to this work. We have grown quite accustomed to seeing our dreams become actualities almost over night. The past year has witnessed the actual generation of power in an 80,000-kw. generating station at a coal rate of kw-hr. 20 per cent lower than any previous performance on a commercial scale. May we with confidence look forward to further gains of the same magnitude? May we expect that each new station built will establish a new record for operating performance? Why does each new steam generating station differ so radically from those already built? If we are to answer these questions, we must evaluate the present day tendencies, look backward a bit to see how far we have come, and attempt to look forward.

Important Technical Achievements of the Last Year

1. The operation of the two 40,000-kw. General Electric single-cylinder turbines, in the Philo Station of the Ohio Power Company: The steam is delivered to the turbine throttle at a pressure of 550 lb. per sq. in. gage, and a temperature of 725 deg. fahr., the steam being withdrawn from the turbine after being expanded down to a gage pressure of 155 lb., returned to the boiler room, reheated to a temperature of 725 deg. fahr., and then expanded through the remaining stages of the turbine to a pressure of approximately ½ lb. per sq. in., absolute at the turbine exhaust. This marks the consummation in this country of Ferranti's dream of a reheating cycle. The two units in this station have been in operation since October 14, 1924, and February 24, 1925, respectively. The water rate, corresponding to a load of 40,000-kw., steam conditions being as indicated above and no steam bled from the turbine for feed water heating, is reported to be approximately 8 lb. per kw-hr. In normal operation, steam is bled from two stages of the turbine for feed-water heating. The feed water then goes through economizers before being delivered to the boilers. The air for combustion passes through a preheater before going to the wind box of the chain grate stoker. The flue gases pass through the preheater on their way from the economizers to the stack. The heat consumption for this station has over a week's time been as low as 13,715 B. t. u. per kw-hr. of net station send-out, this performance corresponding to a load factor of 81 per cent for the week.

2. The initial operation of the Crawford Avenue Station of the Commonwealth Edison Company in Chicago: The turbines in this station are designed for substantially the same steam conditions as the turbines in the Philo Station. The three turbines in the Crawford Avenue Station are of the cross compound type and were built by three different manufacturers—

a. 50,000-kw. unit—C. A. Parsons
b. 60,000-kw. unit—General Electric Company
c. 50,000-kw. unit—Westinghouse

Two surface condensers with vertical tubes connect direct to the exhaust casing of the low pressure element of each of these turbines. Each of these three turbines was built on a new design and they present many interesting features. Due to the new design of low pressure exhaust nozzle and condenser, new features have been embodied in the turbine foundations, the building layout and the arrangement of auxiliaries. The Crawford Avenue Station has been in operation only a few months and as yet the single stage of reheating of the steam during its expansion has not been used.

3. The construction by the General Electric Company of a 3000-kw. turbine, running at 3600 rev. per min., for operation in the Weymouth Station of the Edison Electric Illuminating Company, with a steam pressure of 1200-lb. per sq. in. gage and a steam temperature of 700 deg. fahr. at the turbine throttle: This turbine will exhaust against a back pressure of approximately 350-lb. per sq. in. gage, its steam being first returned to the boiler room to be reheated to 700 deg. fahr. and then discharged into the main steam header of the station. Only one boiler for operation at 1200-lb. per sq. in. gage has been installed at the present time. This high pressure boiler and the turbine which serves as its reducing valve will soon be completely erected and ready for operation.

4. The operation in the Colfax Station of the Duquesne Light Company in Pittsburgh, of two 35,000-kw. Westinghouse turbines, with four-stage bleeding of steam to raise the feed water to a final temperature of approximately 350 deg. fahr. before it is returned to the boilers: This marks the extreme development of the regenerative cycle in turbine room operation.

5. The operation of four 30,600-sq. ft., double-ended Stirling boilers, with 22,464-sq. ft. economizers in the Lake Shore Station of the Cleveland Electric Illuminating Company: These boilers and economizers, equipped with pulverized fuel burners and furnaces—

*Annual Report of Committee on Power Generation.

Vern E. Alden, Chairman,

H. A. Barre,	H. A. Kidder,	M. M. Samuels,
E. T. Brandon,	J. T. Lawson,	F. A. Scheffler,
H. W. Eales,	W. H. Lawrence,	R. F. Schuchardt,
Louis Elliott,	C. O. Lenz,	Arthur R. Smith,
N. E. Funk,	James Lyman,	N. Stahl,
C. F. Hirshfeld,	W. E. Mitchell,	B. Tikhonovitch,
Francis Hodgkinson,	J. E. Moultrop,	W. M. White.
Peter Junkersfeld,	John C. Parker,	

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y., June 23, 1925.

each of the latter having a volume of 29,150 cu. ft., have shown on test an efficiency of 92.9 per cent at 140 per cent of normal rating, and an efficiency of 89.8 per cent at 270 per cent of normal rating. These same boilers have operated at an average gross efficiency of as high as 90.4 per cent for a month's time. These results have been obtained with coal running as high as 11 per cent in ash and as low as 12,600 B. t. u. per lb. in heat value. The sulphur was as high as 3.5 per cent and the coal ash melted at approximately 2150 deg. fahr.

Operating efficiencies in connection with the 29,085 sq. ft. double-ended Stirling boilers in the Trenton Channel Station of the Detroit Edison Company, have been only slightly lower than the results quoted above for boilers installed in the Lake Shore Station in Cleveland. Each of these boilers in the Trenton Channel Station is equipped with two 9492 sq. ft. economizers. The coal is fired in pulverized form, and the furnace has a volume of 25,140 cu. ft. These operating results in the Lake Shore Station and the Trenton Channel Station, with the unburned fuel loss reduced to a small fraction of 1 per cent and the temperature of flue gases reduced to from 230 deg. fahr. to 250 deg. fahr., present an achievement undreamed of a few years ago.

6. The operation of the 18,010 sq. ft. Babcock & Wilcox cross-drum boilers in the Cahokia Station of the Union Electric Light & Power Company of St. Louis: These boilers are twenty tubes high in the main tube bank and are not equipped with economizers. The coal is burned in pulverized form. The furnace has a volume of 12,850 cu. ft. Burning a most inferior grade of southern Illinois coal, these boilers have shown on test an efficiency of 85.9 per cent at 148 per cent of normal rating and an efficiency of 82.1 per cent at 260 per cent of normal rating. The average gross boiler-room efficiency in the Cahokia Station has run as high as 81.2 per cent over a month's time. These results are remarkable for two reasons:

a. They were accomplished with very low grade coal.

b. They were accomplished without the use of economizers or air heaters.

7. The successful operation in the Chester Station of the Philadelphia Electric Company, of underfeed stokers, with air delivered to the stoker wind box preheated to a temperature 550 deg. fahr.: A 15,000 sq. ft. boiler, equipped with a 15-retort, 22-tuyere, Taylor stoker with clinker grinder has operated for extended periods at ratings in excess of 300 per cent of normal boiler rating, with air delivered to the stoker wind box at a temperature of approximately 550 deg. fahr. The fuel bed has been free from large clinkers and is as easy to maintain in good condition as in connection with other boilers not equipped with air preheaters. It appears that stoker maintenance will not be greatly increased by use of preheated air. It does appear, however, that furnace walls designed along conventional lines will not withstand the effects of the high furnace temperatures which obtain in connection with the use of preheated air.

8. The further developments in use of water-cooled furnace side walls as exemplified in connection with the boilers installed in the Hell Gate Station and Sherman Creek Station, of the United Electric Light and Power Company in New York, and the boilers installed in the Zilwaukee Station, of the Consumers' Power Company in Michigan.

A novel wall has been in operation since November in connection with one of the stoker-fired boilers in the Lake Shore Station in Cleveland. By water cooling, the inner refractory lining having a thickness of less than 1 in. is maintained at a temperature of less than 2000 deg. fahr., but still at not too low a temperature to slow up combustion adjacent to the wall.

9. The successful use of Cottrell precipitators in the Trenton Channel Station, of the Detroit Edison Company, for the removal of fine ash from the flue gases before they pass out the stack: The ability of this equipment to remove 75 per cent of the solids in suspension in the flue gas has been demonstrated.

10. The successful operation of 70 in. Fuller air-separating type of pulverizing mill in the Cahokia Station, of the Union Electric Light and Power Company of St. Louis: This mill has pulverized 28 net tons of Illinois coal per hour, with a combined power consumption of 294 kw. for the motors driving the mill and the exhauster fan. Coal was pulverized to a fineness so that 65 per cent passed through a 200 mesh screen. This mill and its driving motor occupy a floor space of 13 by 21 ft.

11. The development by the Fuller-Lehigh Company of the "well type" furnace for burning coal in pulverized form: In an experimental furnace 8 ft. square by 8 ft. high, 32,700 lb. of coal per hour have been burned. Such observations as can be made, in connection with a furnace open at the top to atmosphere indicate that the coal is completely burned.

12. The successful operation in several stations of automatic combustion control equipment: Notable installations are those in the Lake Shore Station in Cleveland, Sherman Creek Station in New York, and Devon Station, of the Connecticut Power and Light Company, in Devon, Conn. Reference has already been made to the close agreement between average monthly operating efficiencies in the Lake Shore Station, and the efficiencies obtained under the most carefully made tests. It appears that equipment is now available which will enable elimination in large measure, of the losses incident to the lack of constant vigilance by the firemen.

13. The efficient operation of large single-pass condensers in the Waterside Station, of the New York Edison Company, and the Trenton Channel Station, of the Detroit Edison Company: In these installations less than 1 sq. ft. of surface is installed per kw. of turbine capacity. Ample provision has been made, however,

for the penetration of steam into the tube bank. These installations point the way to possible reductions in the cost of condensing equipment without appreciable reductions in station economy.

14. The placing in operation of five 30,000-kw. and nine 20,000-kw. turbines of the new Westinghouse multi-exhaust Baumann type.

15. The construction by the General Electric Company of two 50,000-kw., 62,500-kv-a., 1800-rev. per min., tandem compound turbo-generators, for the new Richmond Station of the Philadelphia Electric Company, and two 60,000-kw., 60,000-kv-a., 1500 rev. per min., single cylinder turbo generators, for the Fourteenth Street Station of the New York Edison Company.

16. The use of three new methods for insuring the reliability of the power supply for the auxiliaries in large steam stations:

a. In ten new stations recently placed in operation or now in the course of construction, the generator which supplies power for the essential auxiliaries is directly coupled to the main generator and driven by the main turbine.

b. In the Trenton Channel Station, of the Detroit Edison Company, the power for the auxiliaries is obtained from separate turbo generators which operate as condensing machines and constitute a separate power plant within the larger power plant.

c. In connection with the Parsons turbine in the Crawford Avenue Station, Chicago, and the Richmond Station, Philadelphia, the power for the essential auxiliaries is to be obtained from a transformer which is tied direct to the leads of the main generator.

17. The extensive use of waste heat driers and steam driers for removing the moisture from coal before it is pulverized: This is best exemplified by the installations in the Cahokia Station, in St. Louis, and the Trenton Channel Station, in Detroit.

Important Developments of the Past Few Years

These things have come to pass within the last year. Looking back over a slightly longer period, we see the development of the steel-tube economizer for high pressure installations; the development of the inter-deck and radiant heat superheaters; the development of the air-cooled furnace for pulverized fuel, with a water screen for protecting the furnace floor; the development of the air preheater; the use of the closed system of ventilation with radiator type coolers for large turbo generators; the widespread use of deaerators and evaporators; the all but universal swing to the use of electric-driven auxiliaries; the newer developments in the design of boiler settings for chain grate stokers to insure a thorough mixing of the rich gas stream which rises from the front end of the stoker with the excess air which comes up through the rear end of the stoker, so as to enable a minimum of excess air to be used; and the development of the underfeed stoker for total furnace depths up to 19 ft. 8 in. All of these things were unknown as commercial achievements and most of them undreamed of five years ago.

The length of the strides which we have taken may be visualized by reference to the most interesting address delivered by Mr. W. H. Patchell, at the time of his inauguration as president of the British Institution of Mechanical Engineers on February 21, 1924. As a result of a review of the situation in this country and abroad, Mr. Patchell presented the operating efficiencies for thirty-six stations in England, twenty-five stations in the United States, and one station—the Gennevilliers Station—in France. The heat consumption per kw-hr. for the most efficient station in England was given as 20,150 B. t. u. The heat consumption for the most efficient station in the United States was given as

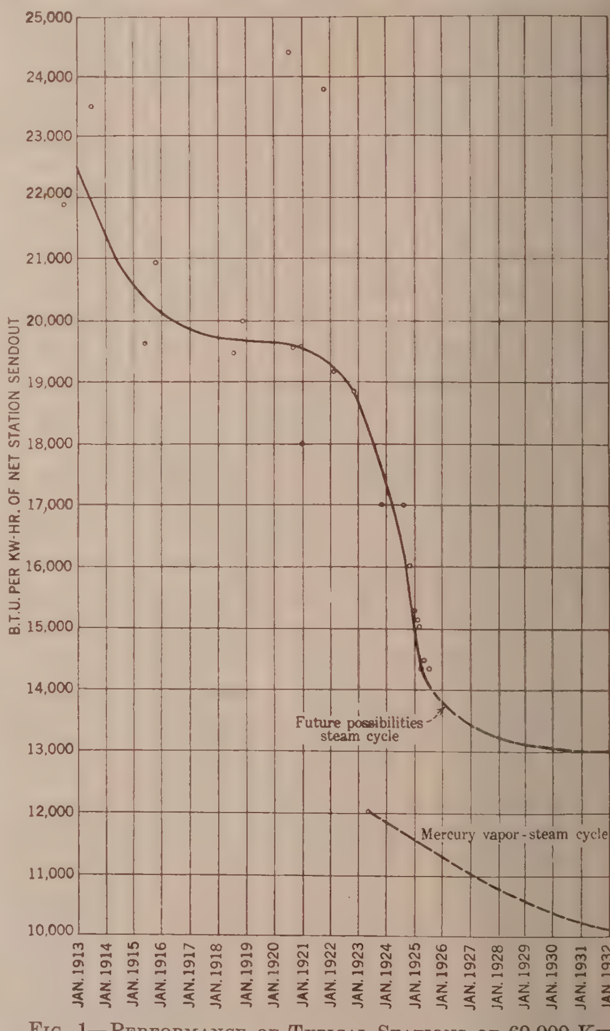


Fig. 1—Performance of Typical Stations of 60,000-Kw. Capacity and Higher Plotted Against Dates of Initial Operation of Stations

18,030 B. t. u., and the heat consumption for the Gennevilliers Station in Paris was given as 22,240 B. t. u. We have referred earlier in this report to the remarkable performance of the Philo Station of the Ohio Power Company, which has been as low as 13,715 B. t. u. per kw-hr.

These same facts referred to in the preceding paragraph may be visualized by reference to the curves in Fig. 1, which show the trend of performance of typical

stations plotted against the dates of initial operation of these stations. This curve is not the product of a disordered imagination, but represents the weighted average in connection with the performances plotted for twenty-two stations. At first glance, the curve appears to have a very peculiar shape. Further analysis indicates that there was a very definite reason for the slowing up of power-station development during the war period, and the extremely high prices of coal during the period from 1920 to 1922, inclusive, in no small measure account for the marked improvement in the performance of stations which have gone in service within the last six months.

The dotted extension of the curve shown on Fig. 1 is our estimate as to the future possibilities in the way of improved performance for a station designed to operate on the straight-steam cycle with a single stage of reheating. Obviously, this curve has to flatten out. We have also shown the over-all performance for a combined mercury vapor and steam station, which is indicated by the performance of the mercury-vapor turbine and boiler in the Dutch Point Station of the Hartford Electric Light Company, and we have shown by means of a dotted curve our estimate as to the future possibilities of the combined mercury vapor and steam cycle.

One might well gain the impression that the possibilities for further improvement in steam-station design have been almost exhausted. This fact is hardly the case. There are at least three major possibilities immediately ahead which will result in higher operating efficiencies for our steam generating stations:

a. The further development of commercial equipment for use in the application of the mercury vapor-steam cycle.

b. The development of superheaters, high-pressure steam piping, valves and turbines for operation in connection with steam temperatures of 800 deg. fahr. or higher.

c. The use of hydrogen or some equally suitable gas as the cooling medium in connection with closed ventilating systems for turbo generators, and the development of new generator designs which will take advantage of all the possibilities of this new cooling medium.

It is perfectly true, however, that while there has been a drop from approximately 18,000 B. t. u. per kw-hr. to 14,000 B. t. u. per kw-hr. in the last eighteen months, a further reduction from 14,000 to 10,000 B. t. u. per kw-hr. cannot be looked for unless use is made of the mercury vapor-steam cycle, with comparatively high pressure used in connection with the mercury vapor boiler and the most efficient possible layout in connection with the steam end of the station. As far as further reduction in the fuel cost in connection with large steam stations goes, work is being done on the law of diminishing returns. A point has already been reached where further gains are going to be very difficult of attainment.

The report thus far has dealt in large measure with the technical achievements and with the reductions in heat consumption in connection with our newer stations. Our real function as power station engineers, however, is to deliver power on the station bus-bars at the lowest possible cost per kw-hr., and it is in the analysis of the elements which go to make up the cost per kw-hr. that we find the real answer as to the most profitable trend for future power station development.

The total cost of each kw-hr. delivered on the station bus-bars is made up of four major elements:

a. Operating labor and superintendence.
b. Maintenance.
c. Fuel cost.
d. Fixed charges on the investment.

The so-called operating costs which most of us talk

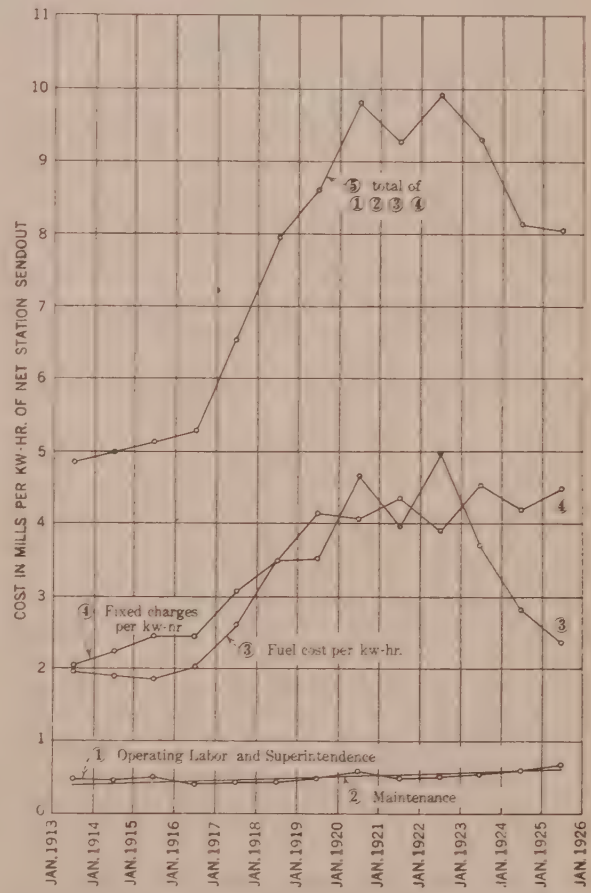


FIG. 2—TREND OF OPERATING COSTS AND FIXED CHARGES FOR TYPICAL STATIONS OF 60,000-KW. CAPACITY AND HIGHER PLOTTED AGAINST DATE OF INITIAL OPERATIONS OF STATIONS

about when we discuss power costs, is made up of items a, b and c. Accounting systems commonly used do not spread fixed charges so as to allocate so many mils to each kw-hr. generated, and accordingly many of us lose sight of them. It is perfectly obvious, however, that the interest and the taxes paid in connection with an investment in power stations and the money which must be set aside each year to provide for renewals due to depreciation and obsolescence are just as tangible elements entering into the cost per kw-hr. as the money

which must be paid for fuel to generate that same kw-hr.

In Fig. 2, is shown the trend of operating costs and fixed charges of typical large power stations plotted against the dates of initial operation for these stations. As in connection with Fig. 1, only power stations of 60,000-kw. capacity and higher are considered. An endeavor has been made to take into account all the

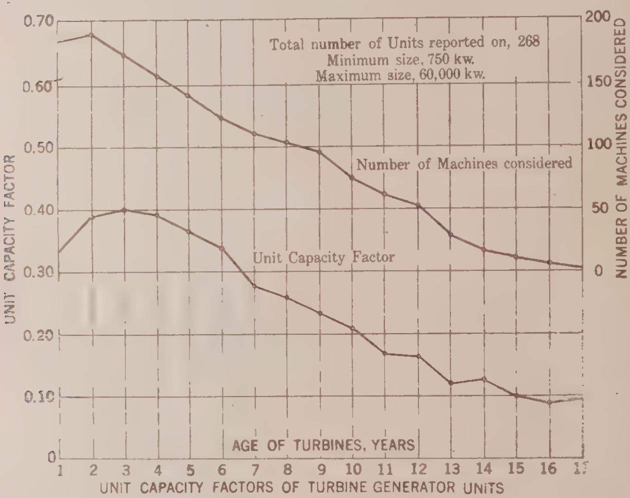


Fig. 3—Unit Capacity Factors of Turbine-Generator Units

different factors in the derivation of these curves. Some of these factors are as follows:

1. The variation in the cost of labor, both for operation, maintenance, and for construction work during the period from 1913 to 1925.
2. The variation in material costs and equipment costs.
3. The variation in coal prices (costs of coal delivered in the bunker for a power station in Baltimore has been taken as the basis).
4. The variation in the cost of new money in connection with financing which has been done during succeeding years.
5. The variation in taxes which have as their basis the investment in power stations.
6. The variation in the probable use factor of equipment placed in service during succeeding years. The average load factor of the system, the outages of equipment for inspection and repairs, and the amount of spare capacity considered necessary, are factors which go to make up the use factor in connection with the station.
7. The decrease in man hours of operating labor per kw-hr. incident to certain developments in power-station design.
8. The tendency towards the decrease in cost per kw. of installed capacity due to certain trends of power station design, and the conflicting tendency towards increased power station costs due to other trends of power station design.

The thing which stands out from an inspection of the curves in Fig. 2, is the relative trend of the fuel cost and the fixed charges during recent years. There has been a marked reduction in fuel cost due to the improvements in power station design and due to the declining price of coal. There is a definite upward tendency, however, in connection with the fixed charges per kw-hr., and as the matter stands at the present time the fixed charges are 4.5 mils per kw. as compared to a fuel cost of 2.4 mils per kw. For those stations which are located in closer proximity to the coal mines and have the advantage of lower coal costs, the fuel costs will be still further reduced, assuming, of course, the same modern power station design for the best possible economy. The fixed charges, however, will remain at 4.5 mils.

The indications are that if we strive for lower fuel costs by the use of more efficient stations, the fixed charges per kw-hr. will rise still higher, and the increase in fixed charges per kw-hr. will more than offset the decrease in fuel cost per kw-hr.

The real job which the power station engineer has ahead of him is to decrease the fixed charges per kw. and to reestablish the proper balance between fuel costs and fixed charges.

Certain executives and engineers will, no doubt, state that the fixed charges per kw-hr. in the newer stations which they are placing in operation, are very much lower than the curve indicates in Fig. 2, this being for the reason that these newer stations are carrying the base load for their system and are operating at an extremely high use-factor. Our answer is that this is a transient condition. Each new turbine or station operates on base load only for so long a time as it constitutes the most efficient turbine or the most ef-

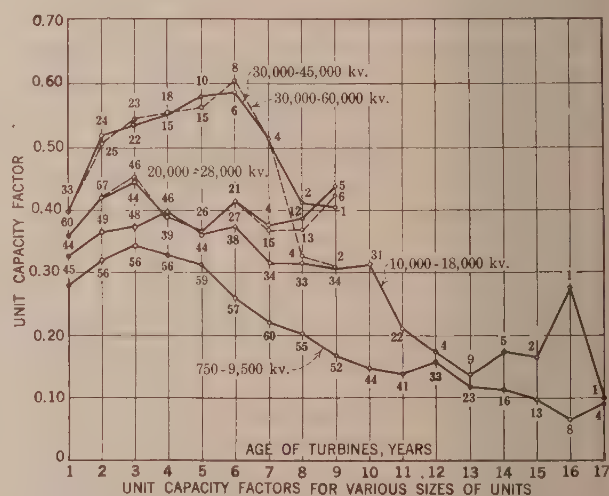


Fig. 4—Unit Capacity Factors for Various Sizes of Turbine-Generator Units

ficient station generating power for that particular system. The curves given in Figs. 3 and 4 tell this story in a very striking manner. They show that the generating unit is heavily loaded during the second and third years of its life, but that from then on the loads carried during succeeding years gradually decline. These curves given in Figs. 3 and 4* constitute the

*The data given in Figs. 3 and 4 was compiled by the Turbine and Generator Committee, Association of Edison Illuminating Companies, and embodied in the report of that Committee for 1923.

actual operating history as regards kw-hr. generated during succeeding years by 268 turbines ranging in size from 750 kw. to 60,000 kw.

It is perfectly obvious that fixed charges per kw-hr. must be determined by taking the total fixed charges on a piece of equipment or on a station during its life and spreading them over the total number of kw-hr. generated by that particular turbine or station during its useful life.

It is of interest to note from Fig. 3, that the average unit capacity factor during the 17-year period on the 268 turbines is approximately 25 per cent. The curve of fixed charges given as a part of Fig. 2 was based on the assumption that for generating stations placed in operation in 1913, the average unit capacity factor during their life would be 31 per cent, and for stations placed in operation in 1925, the average unit capacity factor would be 36 per cent. The evidence would tend to indicate, therefore, that if error has been made, it is on the side of showing the fixed charges per kw-hr. too low rather than as too high.

Tendencies in the design of steam generating stations may be classified under four heads:

1. Tendencies which improve the reliability of the power station, increase its cost, but do not appreciably affect the operating efficiency; for example:

   a. The use of house turbines, auxiliary generators, and storage batteries for insuring the auxiliary power supply.

   b. Isolated-phase layout and the use of reactors and other protective devices in the switchhouse.

   c. The duplication of auxiliaries, and provision of excessive amounts of spare capacity in boilers and turbines.

2. Tendencies which decrease the coal consumption per kw-hr. and increase the cost of the power station; for example:

   a. The use of excessively high steam pressures taken together with a single stage of steam reheating during its expansion.

   b. The use of pulverized fuel burning equipment.

   c. The use of adjustable speed motors for driving auxiliaries where saving in power consumption at light loads is the consideration.

   d. The use of air heaters or economizers usually falls in this classification.

   e. The use of an excessively large amount of surface in the surface condensers for the main turbines.

3. Tendencies which decrease the coal consumption per kw-hr. and also result in a reduction in the cost of the power station and perhaps in the cost of operating labor; for example:

   a. The use of electrically-driven auxiliaries.

   b. The use of moderately high steam pressures without reheating.

   c. The use of the highest steam temperatures which are possible with existing materials.

   d. The use of large turbines and large boilers.

   e. The use of three or four-stage bleeding for raising the temperature of feed water to within 75 deg. or 100 deg. of saturated steam temperature.

   f. The use of large mills for pulverizing coal.

4. Tendencies which add to the cost of the station without improving either its reliability or appreciably decreasing its coal consumption; for example:

   a. Insufficient care given to grouping of equipment and waste space in power station building.

   b. Too many architectural frills.

For a particular set of operating conditions, some of the examples which have been cited above as falling in one classification may really classify themselves under an entirely new head. An inspection of the curve given in Fig. 2, however, presses home the conviction that every tendency which makes for an increase in the cost of steam generating stations, and correspondingly increases the fixed charges, must be viewed with suspicion. The burden of proof should be on the designing engineer to show why the particular feature should be embodied in the design. The same line of reasoning indicates that the designing engineer should give intensive study to those tendencies of power station design which hold forth promise of giving lower first costs and lower fixed charges, as well as lower fuel costs.

Now, turning to the field of hydroelectric plant design and operation, we find somewhat different conditions obtaining and no such revolutionary changes taking place as there are in connection with steam station design. There is one definite tendency in hydroelectric plant design very similar to that which has made itself evident in recent years in steam station design, namely, the trend toward the use of larger water-wheel turbines and larger water-wheel generators. In the main, the objective is not higher efficiency, but lower cost per unit of installed capacity. The tendency seems to be toward using as large water-wheels as the turbine manufacturers can build in single runner vertical turbines for the operating head that is to be developed. An effort is then made to match this water-wheel turbine with a generator which will permit delivering the full output of the water-wheel turbine to the station bus-bars. Water-wheel type generators of 65,000 kv-a. have been built. It is true, however, that these generators have been built for special plants, and that only in a few cases has a maximum rating of 35,000 kv-a. been exceeded. However, the size of generators is entirely economically dependent upon the individual case and its relation to the size and charging current of the transmission lines, if not limited by the maximum possible output from the water-wheel turbine.

In the future, it is going to be even more important than in the past to build water-power plants with a low first cost per unit of capacity. This must be done if the power from water-power plants is to compete with power from the larger and more efficient steam generating stations. The use of larger generating units is the one means that holds forth most promise for decreased station costs. Further, with the greatly increased total loads in connection with the big power systems, it becomes perfectly feasible to install generating units of large capacity. The tying of a number of plants into the transmission network of a large system makes single unit water power developments practical, and combined with remote or supervisory control, such developments permit a simple layout, resulting in low operating expense. This is particularly the case with some of the smaller power sites which are relatively

close to existing developments. Simplicity of layout is very desirable, as it has a direct effect on reduction of costs, both capital and operating. The importance of this trend toward the use of larger generating units in connection with hydroelectric plants has made it seem worthwhile to prepare a symposium of the views of the engineers of the several different manufacturing companies on this particular subject. These statements are quoted herewith:

Statement by W. M. White. There are five principal factors which limit the maximum capacity of hydroelectric equipment. These reasons are given below:

a. Shipping facilities.
b. Material size limits.
c. Economical generator speeds.
d. Manufacturing limits.
e. Strength and life of parts.

Shipping facilities are an important factor on many developments, the runner being the item most frequently affected. Runners for medium and low heads may be sectionalized, but this is expensive, and for high heads it is doubtful whether sectionalized runners can be made sufficiently strong. Other parts of the turbine can usually be sectionalized to accommodate shipping, but the runner is usually the limiting factor.

The sizes of available material is another important limiting factor. Shafts must be forged from steel ingots. At the present time, the largest ingots obtainable are about 80 in. in diameter, so that the shaft flange must come within a reasonable margin below this diameter. This factor seems to be one of the important points and limits size to about 100,000 h. p. at 200 ft. head, or 110,000 h. p. at 300 ft. head.

Economical generator speed is the most important factor for low head developments. The cost per kw. of generator equipment increases rapidly for speeds below 80 or 90 revolutions. Seventy rev. per min. is about the minimum for economical generator construction and this fact places the limit at about 12,500 h. p. at 20 ft. head and 30,000 h. p. at 40 ft. head.

Incidentally, the runners for large low head developments are usually larger than can be shipped in one piece, but propeller-type runners can readily be made in several sections so that shipping is not the most important factor for low heads.

Manufacturing limits are another important factor, that is, there is a maximum height and diameter of parts which can be handled with present shop tool equipment. Larger tools can be designed and constructed, but with the limited use for such equipment there is a question as to whether or not this is economical. At the present time, most of the manufacturers of hydroelectric equipment are able to handle diameters up to 28 or 30 ft. and heights of from 10 to 12 ft. Without exceeding these limitations, it is possible to build units for about 52,000 h. p. at 70 ft. head, 70,000 h. p. at 100 ft. head, and 90,000 h. p. at 150 ft. head.

Strength and life of parts is another important factor limiting the maximum capacity of hydroelectric units. For high head developments, the question of penstock material is sometimes a limiting feature and practically limits us to 100,000 h. p. capacity under 2000 ft. head and 60,000 h. p. capacity under 1000 ft. head. These turbines would be of the impulse type. For heads between 800 and 400, the question of strength and life of the runner is an important factor. Pitting occurs more frequently under these high head conditions and it is, therefore, advisable to make the diameters larger in order to decrease the relative velocities in an effort to decrease this pitting. Smaller runners of higher specific speeds could deliver the same h. p., but their life and strength is questionable and in all probability they would pit seriously in a short time. These factors seem to indicate that 110,000 h. p. is the upper limit for heads of 400 to 800 ft., using the reaction type of runner.

These limitations are based not on a consideration of either hydraulic equipment or electrical equipment alone, but on a combination of the two as a hydroelectric unit. Undoubtedly, turbines of larger capacity could be constructed for heads below 100 ft. and generators of larger capacity for the high heads, but considering the combined hydroelectric unit, the values given represent the upper economical limit.

Statement by E. V. Gibbs. The curve shown on Fig. 5 indicates the maximum h. p. capacity for which it is possible to build water-wheel turbine units for heads ranging from 20 ft. to 600 ft. The specific speed, corresponding to the different heads, is also shown in this same figure—No. 5, and the formula for the specific

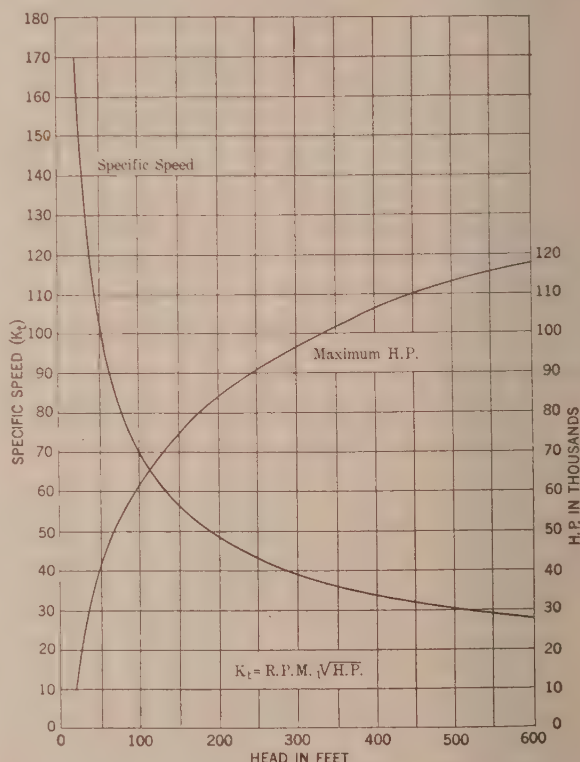


Fig. 5—Curve Showing Specific Speed and Maximum Capacity for Water-Wheel Turbines Designed for Different Operating Heads

speed at 1 ft. head is given. At the present time the maximum h. p. curve is considered the maximum output of a single runner turbine unit under the corresponding turbine head.

From any given head up to 600 ft., a specific speed from the curve can be found, thus leaving two unknown factors in the formula to be determined, viz., the speed and power. Either one of these unknown factors will have to be assumed under the given head, and this reduced to an equivalent at 1 ft. head by using the formula for speed which varies as the square root of the head.

The h. p. under the given head can be reduced to the equivalent at 1 ft. head by the formula that h. p. varies as the square root of the cube of the head. If it is desirable to obtain the speed of the maximum unit under the given head, take the h. p. from the curve for maximum h. p. shown on Fig. 5, and figure the same way to obtain the proper speed. While it is possible to build a turbine to operate under a 1000 ft. head, the

field for pressure turbines under this high head needs further exploration before it would be wise to recommend them.

Statement by R. V. Terry. Relative to maximum h. p. of hydraulic turbines, the Newport News Shipbuilding and Dry Dock Company is prepared to build for different operating speeds and heads:

Since specific speed, $N_s = \dfrac{N\sqrt{P}}{H^{\frac{5}{4}}}$, the maximum power ($P$) for a given speed ($N$) and head ($H$) will depend upon the maximum specific speed selected for the particular head in question. The so-called Experience Curve, $N_s = \dfrac{5050}{H+32} + 19$ has been used in the past. This curve gives values of N_s too low in working up data for this report, a maximum specific speed for a given head equal to $\dfrac{632}{\sqrt{H}}$ was used.

Fig. 6 shows the maximum specific speed, maximum power and maximum speed for a given power that is proposed, using the head as a starting point. If the maximum power for a given speed and head is desired, this can be obtained from Fig. 6 or directly from the formula, $P_{max} = \dfrac{632^2\ H^{3/2}}{N^2}$. Fig. 7 shows the formula in graphical form. In using the formula, one must, of course, bear in mind the limitation of power for a given head due to physical dimensions and shipping facilities. This

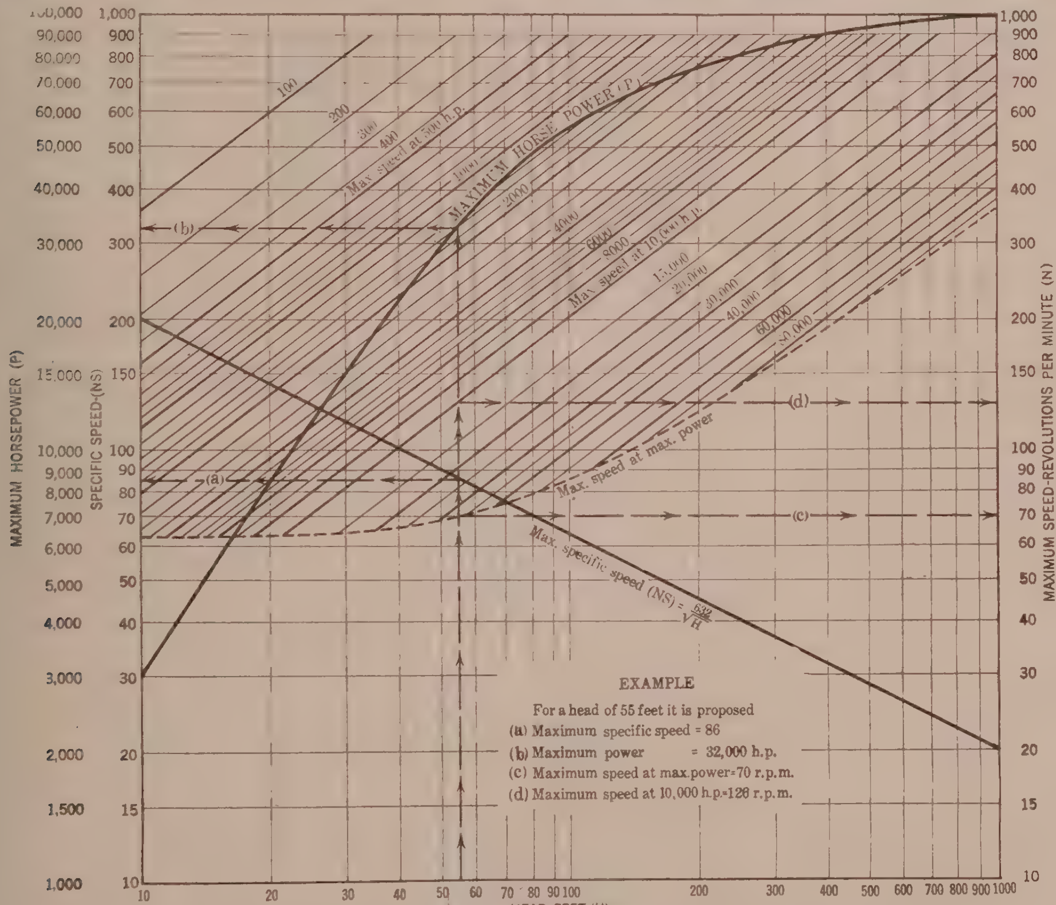


Fig. 6—Curve Showing Maximum Specific Speed, Maximum Capacity and Maximum Operating Speed for Water-wheel Turbines Designed for Different Operating Heads

for heads from 10 to 450 ft. and too high for 450 to 1000 ft. Specific speed should not be used as an absolute basis for the selection of the maximum head; other factors, including the draft head, should be given due consideration. However, for a number of years the formula, $\dfrac{632}{\sqrt{H}}$ has been used for the maximum specific speed to which it is possible to go, except under expecially favorable conditions as to low draft head. A few installations of the propeller type have been made with specific speed beyond values given by the latter formula, but they may be considered experimental installations. Therefore, Company is prepared to build turbines as physically large as can be conveniently transported and erected.

A lower value of specific speed than that given above may be assumed for a given head. This simply means that for a given unit there is a certain choice of speeds. However, as stated previously, the power for a given head and speed will be higher, the higher the specific speed selected.

Statement by T. A. Worcester. With the larger units, the first cost, including building and operating cost, is less per kv-a. than with the smaller units. There is a physical limitation, however, to the size of units which can be built with present day materials and types of construction; and the kv-a. capacities

vary with the speed of the units. These maximum size units are approximately as follows:

10,000 kv-a.	at 720 rev. per min.
20,000 "	" 600 "
30,000 "	" 514 "
55,000 "	" 400 "
80,000 "	" 300 "
110,000 "	" 200 "

This table might be carried to lower speeds and larger sizes. For instance, it is theoretically possible to build a 130,000 kw. machine at 100 rev. per min., but it is questionable if it is at all desirable to put so much capacity in a single unit.

Statement by F. C. Hanker. The 1924 water-power developments have been characterized by studies and investigations of a number of very large water-power developments in the north and northwest parts of the country. These developments have involved consideration of water-wheel generators approaching the limits of commercial design. The following gives an approximate tabulation of the economic design limitations of vertical water-wheel generators at the present time:

5,000 kv-a.	at 720 rev. per min.
12,000 "	" 600 "
40,000 "	" 514 "
45,000 "	" 400 "
70,000 "	" 300 "
100,000 "	" 200 "
75,000 "	" 100 "

This tabulation assumes that the more usual conditions of 60 cycles, 13,200 volts, 80 per cent overspeed, and normal flywheel effect apply and that standard commercial material is employed. At speeds below about 300 rev. per min., the physical dimensions of parts became a limiting factor. Low speed water-wheel generators are probably the largest pieces of material with which the electrical industry has to deal. When the dimensions become so great that special shop space and shop tools must be provided for the machine operation, the entire expense of this special equipment must be borne by such a relatively small number of machines that the cost becomes prohibitive. At the present time, the largest machine tools in this country will accommodate a frame bore (which is the same as the outside diameter of the armature punchings) of not more than 37 ft. This limiting dimension has been approached by the ratings given in the above table for speeds below 300 rev. per min. It appears quite probable that these limiting conditions will be reached by a few water-wheel generators in the near future. In general, machining limitations are reached before the transportation limitations become a serious factor since the generator can be separated into parts and a large amount of the assembling done in the power house location if necessary without greatly increasing the over-all expense.

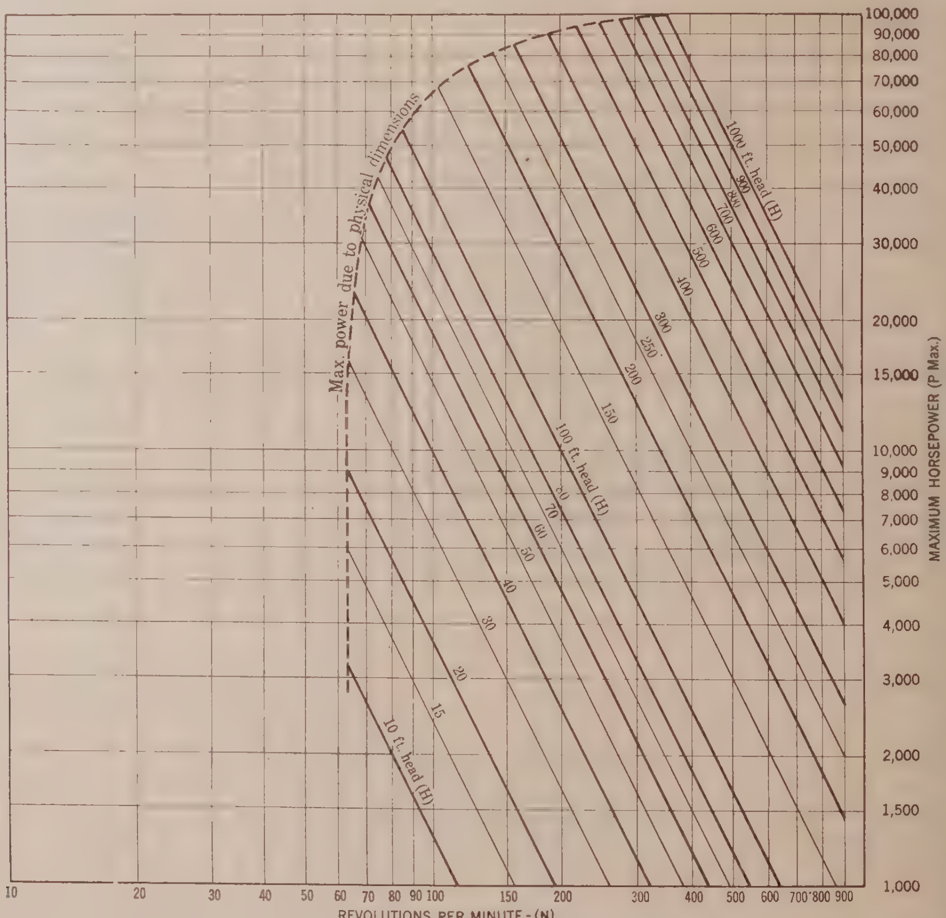


FIG. 7—CURVE SHOWING MAXIMUM CAPACITY FOR WATER-WHEELS DESIGNED FOR DIFFERENT OPERATING HEADS AND OPERATING SPEEDS

TREND OF MODERN PRACTISE

The manufacturers seem to feel that automatic generating stations are growing in importance, but they,

together with the majority of the operating men, feel that the complete automatic hydroelectric station is limited to the smaller sizes, there being two different reasons for this: In the first place, as the size of the installation increases, the complexity of the operating conditions determining the amount of power to be supplied from the station also increases, this being something that is controlled, *not* by the station itself, but rather by system conditions; also in important installations, considerable judgment on the part of the load dispatcher is required for the best system operation, which cannot be supplied by any automatic station equipment. In the second place, there is no entirely satisfactory way of supplying the initial starting impulse for the control of the full automatic station. Voltage conditions which are satisfactory in railway stations will not do; drop in frequency is not satisfactory; so that, generally, the water level appears to be the most satisfactory means of control, and this very materially limits the scope of the automatic station.

However, automatic stations with supervisory or remote control are quite different and developments along this line have been very rapid. Stations with three generating units and with capacities up to 10,000 kv-a. are now so controlled; several stations of 25,000 kv-a. with this type of control are under consideration. This type of control permits the operation of stations with fewer men and gives these men greater freedom to leave the operating floor to attend to duties at the head gates or in the switch yards.

A somewhat different phase of automatic operation has been proposed by one of the members of this Committee, who points out the advisability of having a unit or units in a given power plant controlled by a gate mechanism of another unit or units in the same station. In other words, the plan of operation consists in starting and stopping units automatically and from the gate motion of other units, so that the gate controls of all units are kept within the efficient range and probably within narrow limits where maximum efficiency is obtained, depending upon the number of units under such control.

While there has been a definite movement toward outdoor substations and the location of all oil switches and transformers outdoors, progress in the matter of putting generating equipment outside has been very slow, the difficulty being, apparently, to provide suitable housing in case it is desired to dismantle a generator. However, several stations have been built with a very low superstructure with an outside gantry crane and with movable roofs over the individual generators, which can be rolled back so that the gantry can be used to dismantle any particular unit.

A noticeable tendency in connection with hydroelectric plants constructed in the west during the last two or three years, has been the trend toward more permanent construction. Many of the earlier installations used open conduits. On all important developments now being made, these open conduits are being superseded by tunnels. Pipe lines that were formerly placed in trenches are now being placed entirely above the ground and carried in concrete saddles. The larger amounts of power that are being transmitted call for higher voltages, which in turn call for types of construction that are far more lasting and dependable than the wooden pole lines formerly used.

In the matter of station auxiliaries, there is considerable tendency to get away from direct-connected exciters on the main generator shaft, making the main generators easier to dismantle and reassemble. In the matter of excitation, many stations use a combination of a waterwheel and a-c. motor coupled to the same d-c. exciter, so that if one of the prime movers fails the other will continue to drive the exciter.

Several new European types of high-speed turbine runners are coming on the market in America. These appear to have considerable promise on account of their high efficiency.

There are instances this year of the use of babbitted bearings on vertical shaft turbines in place of lignum-vitae bearings to reduce maintenance expense.

Increased use of motor-driven, flyball governors is noticeable.

A subject which has received special study by both operators and manufacturers during the last year is the pitting of turbine runners, both as to the exact nature of the pitting, cavitation or corrosion itself, and as to the causes thereof. The three principal causes of pitting are believed to be excessive draft head, excessive specific speed and poor design. There is considerable difference of opinion as to the relative importance of these causes. The drive for high specific speeds in the last few years is blamed by some for the recent increase in pitting troubles.

A subject that has accasioned considerable discussion is the omission of governors from hydroelectric units, particularly when operating in large interconnected systems. The suggestion that governors be omitted in such cases except as safety shut-down devices, has met with considerable opposition among operating men. The proper design, characteristics and functioning of governors for hydroelectric units operating in parallel with steam electric units, are questions which are now receiving intensive study.

In the case of low head-water power developments on streams with widely fluctuating flow, there is an increasing tendency to secure the maximum possible output under existing limitations of property and flowage rights by the use of crest gates or movable dams of various types.

A considerable amount of experimental work has been done on draft tubes, but there does not seem to be any general agreement as to which type is the most satisfactory. Those which apparently indicate the highest efficiency are usually very much more expensive to build. It is in connection with the low head installa-

tions that the greatest care must be taken in the design of the draft tube. The great activity in draft tube design in connection with low head plants has been brought about by the increased specific speed of units wherein a greater percentage of energy is discharged from the runner. It seems unlikely that lower specific speeds will be adopted, but, on the contrary, more likely that an effort will be made to adopt higher ones, so that the problem of the draft tube will be with the Committee for sometime to come. It seems inevitable that some type of draft tube providing radially expanding passages must be adopted to best preserve the whirling energy from the high specific speed runners. It is important, however, that methods be developed whereby these draft tubes may be installed at moderate cost.

Conclusion

Much of the subject matter of this report falls more specifically within the scope of the American Society of Mechanical Engineers than of the Institute. We feel, however, that the members of the American Institute of Electrical Engineers should have called to their attention the trends in the art of power station design and operation. With this thought in mind, this report has been prepared, and deals not with details of design and operation, but with tendencies and trends. We had this same purpose in mind in scheduling one session of the Spring Convention at St. Louis for a symposium dealing with power station design. Certainly those of our members who are associated with companies generating large blocks of power, cannot afford to lose touch with the field of power station design and operation.

For those of our members who care to delve deeper into detailed discussions of the subjects briefly referred to in this report, we recommend a careful reading of the reports of the Prime Movers Committee, the Electric Apparatus Committee, and the Hydraulic Power Committee, of the National Electric Light Association. We also commend to your attention the wonderfully interesting series of papers presented at the World Power Conference in London. The papers presented before this Conference covered in an authoritative manner practically every problem of interest to the power station engineer.

A subcommittee of your Power Generation Committee, under the chairmanship of Mr. A. R. Smith, is working on a specific problem which we think is of very definite interest: There is a lack of common terminology and well-defined terms in the discussions which are heard, from time to time, dealing with power station operating costs and performance. It is felt it would be very much to the advantage of the industry that all should speak a common language. This Committee is trying to set up a reasonable terminology and definition of terms which will have the best chance of acceptance by the engineers who have occasion to discuss the matters referred thereto. It is not the thought of the Power Generation Committee to attempt to impose any set of definitions on the engineers of other societies who also have very vital interest in discussions dealing with power station design and operation. It is our plan to call the importance of this matter to the attention of other committees working in this same field, and by cooperating with the members of these other committees, we hope to arrive at a set of definitions of terms which will be acceptable to all.[1]

TRANSMISSION OF PICTURES NOW ON COMMERCIAL BASIS

The adding of telephotographic service to commercial communication facilities has recently been announced by the American Telephone and Telegraph Company. Picture transmitting and receiving apparatus has been permanently installed at New York, Chicago and San Francisco where public offices have been opened to accept material for such transmission.

The field of usefulness for telephotographic service appears to be widespread. To engineers the possibility of transmitting drawings and designs has a particular appeal. Sketches of machinery or any type of construction, made up in both line and pictorial fashion, would quickly convey information where a written description of a long and difficult character might otherwise be necessary.

Facsimiles of original messages and documents, such as autographed letters, legal papers and signatures, and messages in foreign languages, might be transmitted to great advantage for bankers, accountants, lawyers and real estate dealers. The system has also been used for the dissemination of advertising copy carrying considerable of the pictorial element, where speed has been an important factor.

Interesting experiments in the transmission of finger-prints and quick identification of criminals were made by the Identification Bureau of the New York Police Department for the International Police Conference, held in New York, May 12-16, 1925.

The broad principles of picture transmission have been recognized for years. Their reduction to successful practise required, among other things, perfection of methods for the faithful transmission of electrical signals over long distances and the development of special apparatus and methods which have become a part of the communication art only within the last few years. Prominent among the newer developments which have facilitated picture transmission are the photoelectric cell, the vacuum tube amplifier, electrical filters, and the use of carrier current. None of the systems heretofore devised have been sufficiently developed to meet the requirements of modern commercial service.

1. For Bibliography see pamphlet copy.

The 60-Cycle Distribution System of the Commonwealth Edison Company

BY W. G. KELLEY[1]

Member, A. I. E. E.

Synopsis.—*The purpose of this paper is to describe the Commonwealth Edison Company's 60-cycle distribution system. Energy for this system is generated in five stations and transmitted at 12,000 volts, three-phase, to manually-operated and remote-control substations, the operation of the remote-control substations being under the control of the manually-operated substations by means of control wire and selector switch operation. The larger customers are supplied by means of industrial substations located upon their premises and fed from 12,000-volt, three-phase, underground loop circuits; the general load is supplied by means of 2300/4000-volt, three-phase, four-wire radial circuits from the various manually-operated and remote-control substations.*

The generator capacity was 420,000 kv-a. and the maximum load 379,000 kv-a., as of January 1, 1925, for the 60-cycle portion of the system, exclusive of load carried upon the 25-cycle and d-c. portions of the plant.

Reliability of service is provided by relay-controlled oil switches, current-limiting reactors, duplicate supply lines, and tie points for interconnection of different parts of the system.

The rapid growth of load density in some sections of Chicago will soon necessitate modification of the present distribution system by either an increase of distribution voltage or an increase of circuit capacity. The advantages and disadvantages of the two proposed new systems are now under consideration.

THE present 60-cycle distribution system of the Commonwealth Edison Company, like many others, is the result of the consolidation of a number of independent systems and the subsequent modifications to meet the growing demands of load. Prior to 1898 there were a number of independent plants operating in different sections of the city, employing various systems from 1000 to 2200 volts, 60 to 133 cycles, and d-c. series arc circuits.

As these various systems were consolidated they were changed to 60 cycles, alternating current, with 2300-volt primaries, and 115/230-volt secondaries.

As the majority of the energy was then used for lighting purposes or for small motors, two-wire, single-phase circuits were adopted, having manually-controlled regulators. As larger power loads developed it was found necessary to distribute three-phase service in order to limit the fluctuations in voltage and resulting disturbances upon the single-phase circuits. Three-phase, four-wire, 2300/4000-volt power circuits without regulators were therefore installed, paralleling lighting circuits where necessary to serve the larger power loads temporarily.

After a short experimental period the separate light and power circuits were combined into three-phase, four-wire circuits serving both light and power, thereby taking advantage of the diversity factor between these loads. Three automatic, single-phase regulators were installed, one upon each of the phase wires of the circuit controlled by three contact-making voltmeters and line drop compensators. A neutral compensator was in some cases found necessary in addition to the phase compensators due to the fact that the circuit covered a large area, the three phases being regulated for different points, with a resultant unbalance which could not be adequately compensated for without the unit in the neutral.

The original 60-cycle feeders from the stations to the points of distribution were, in general, built overhead upon streets, as these furnished the most direct and economical routes. However, the city being adequately equipped with alleys, there developed a public demand for the removal of the poles from the streets to the alleys and the elimination of the duplicate pole lines of the power and signal companies. Underground conduit systems were therefore installed radiating from the generating stations and substations and the main feeders were placed underground in the streets, being brought up in the various alleys and connected to the overhead lines. The overhead lines were, in the majority of cases, built jointly with the signal companies and the power wires restricted to those necessary for local distribution. As the load density and the demands of individual customers increased, additional substations were built and the larger customers were connected to the transmission system, industrial substations being built upon the customer's premises.

The electrical energy is generated by steam-driven turbines, the coal being transported from the Illinois fields to Chicago and used in the five generating stations, shown on Fig. 1. These stations are all located upon the Chicago River, Calumet River, or Sanitary Canal, in order to have water accessible for condensing purposes. Energy is generated at both 25 and 60 cycles, the 25-cycle energy being used to supply the d-c. substations in the central section of the city and the substations for the elevated and street railway companies, and the 60-cycle energy being used for general distribution outside of the d-c. district in the center of the city. The combined generator capacity of the two systems was, on January 1, 1925, 847,000 kw., and the coincident maximum for the winter of 1924 and 1925, was 700,000 kw.

The new generator units are built for 60 cycles, of a

1. Of the Commonwealth Edison Co., Chicago, Ill.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

capacity of from 50,000 to 60,000 kilowatts, and the annual growth is now being taken care of on the 60-cycle system.

The purpose of this paper is to describe only the 60-cycle distribution system, and figures given refer only

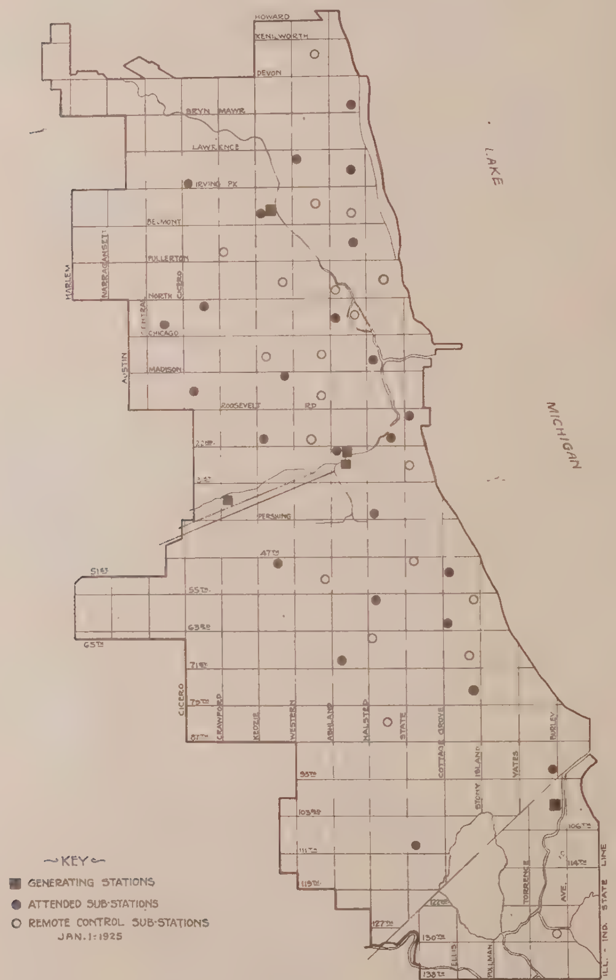


FIG. 1—LOCATION OF GENERATING STATIONS AND SUBSTATIONS

to 60-cycle load and do not include any of the generating transmission or distribution systems for the 25-cycle and d-c. portions of the plant.

The combined 60-cycle generating station capacity was 420,000 kw. as of January 1, 1925, and the 60-cycle coincident maximum for the winter of 1924 and 1925, was 379,000 kw.

The generating stations are inter-connected by 33-kv. tie lines and are further connected by 33- and 132-kv. tie lines on the north, south and west of the city, to other companies operating outside of the city. These tie lines facilitate the interchange of emergency power and permit the more economical use of the various generating units. All of the 60-cycle energy is generated at 12,000 volts, three-phase, and is transmitted at this voltage to the various manually-operated substations in the district surrounding the station. The manually-controlled substations distribute a part of the energy at 12,000 volts, three-phase, to the industrial substations where it is reduced to the utilization voltage and delivered to the customer. The manually-controlled substations also transmit energy at 12,000 volts to remote-control substations, and energy is then distributed at 2300/4000 volts from both the manually-controlled and remote-controlled substations.

The relative location of the generating stations and the two types of 60-cycle substations, are shown in Fig. 1.

Each manually-controlled substation is fed directly from the generating station, by means of two or more transmission lines, the number of such lines being dependent upon the load on the substation. The combined capacity of the transmission lines to a single substation or a group of substations connected by 12,000-volt tie lines being always sufficient in the event of the failure of one of the lines to carry the substation load.

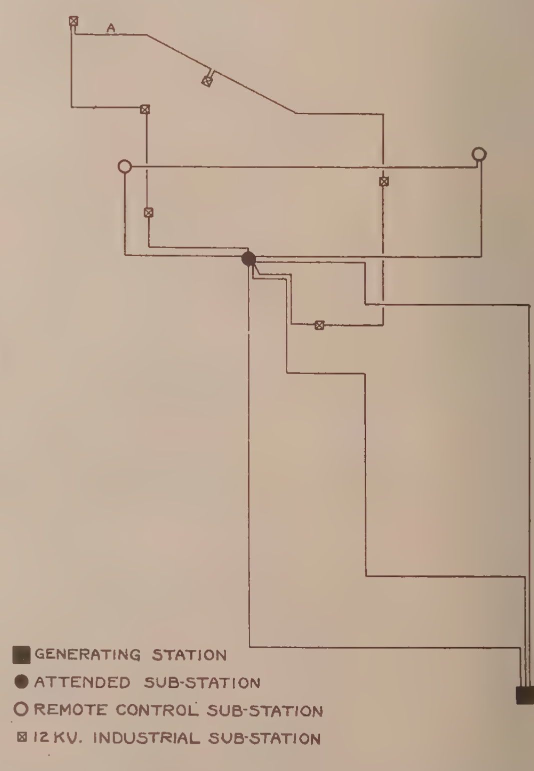


FIG. 2—TYPICAL ARRANGEMENT OF TRANSMISSION LINES BETWEEN STATIONS AND SUBSTATIONS

These transmission lines from generating station to the substation, are, where possible, routed in separate conduit lines either upon different streets or in separate lines upon the same street in order that a failure of one line will not involve the other lines. These transmission

lines are composed of three-conductor, 500,000-cm., paper-insulated, lead-covered copper cables having a nominal rated summer capacity of 7500 kv-a. and winter capacity of 9000 kv-a.

The larger industrial customers are supplied with 12,000-volt, three-phase service by a loop circuit from the manually-operated substation, this loop circuit being lead-covered cable installed entirely underground,

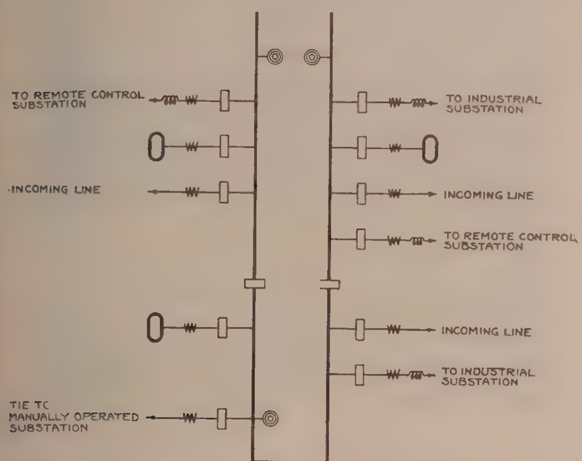


Fig. 3—Line Diagram of 12,000-Volt Bus Connections for Manually-Operated Substation

and the industrial substation being located upon the customer's premises.

As the growth of the load justifies, remote-controlled substations are built, thus reducing the length of the 2300/4000-volt feeders, effecting more economical

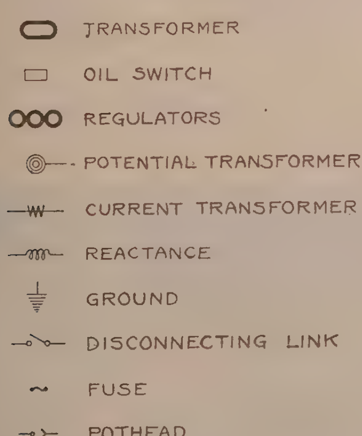


Fig. 4—Symbols used in Accompanying Bus Diagrams

distribution and substation operation. As the number of substations increases with a resulting decrease in the length of 2300/4000-volt feeders, it may be possible to eliminate the separate regulators on the circuit and depend upon the regulation of the transmission system or upon the regulation of the 2300/4000-volt bus at the substations. These substations are under the control of the operator at the manually-operated substation by means of multiple-conductor-control cable and selector switch operation. At present approximately 30 per cent of the 2300/4000-volt load is carried on the

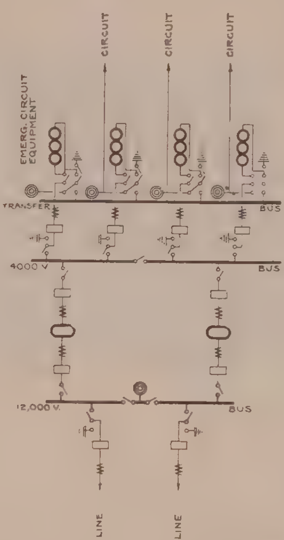


Fig. 5—Line Diagram of Bus Connections for a Remote-Control Substation

remote control substations. A typical arrangement of 12,000-volt, three-phase, 60-cycle lines from generating station to substations and industrial substations, is shown in Fig. 2.

Fig. 6—Exterior View of Remote Control Substation

A line diagram of the 12,000-volt bus, switch and transformer connections in a manually-controlled substation, is shown in Fig. 3, and the key for the symbols in Fig. 4. There are three main incoming lines from the generating station, two lines of the loop to the remote-control substations, two lines of the loop to the industrial substations, one emergency tie to an adjacent manually-operated substation, and the transformers for supplying the 2300/4000-volt bus. The 12,000-volt bus is divided into three sections, inter-connected through oil switches, and the transformers and 12,000-volt lines are connected to the bus through oil switches.

In case of emergency, the 12,000-volt bus can be sectionalized, each section operating as a unit with its incoming line and connected load. The transmission lines from the generating stations to the manually-operated substations are protected at the generating station by oil switches, over current induction type relays, with inverse time element and current limiting reactors having a reactance of 0.5 of an ohm. These transmission lines are also protected at the substation by oil switches and power-directional induction-type relays, with inverse time element. The 12,000-volt lines from the manually-controlled to the remote-controlled substations are protected by current-limiting reactors at the manually-operated substation, having a reactance of 1.2 ohms and by oil switches having over-current induction type relays, with inverse time element. In addition to this protection, each section of the loop between substations is protected by balanced relays, there being oil switches at the remote-controlled as well as at the manually-operated substation.

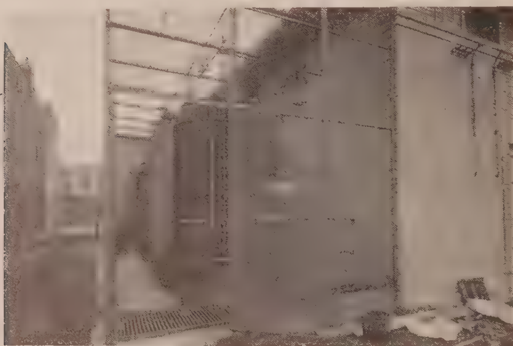


Fig. 7—Exterior View of Remote Control Substation Showing Transformer Enclosure

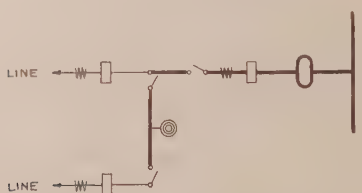


Fig. 8—Line Diagram of Bus Connections for an Industrial Substation

Fig. 9—Switch and Bus Room, Industrial Substation

Fig. 10—Transformer Room, Industrial Substation

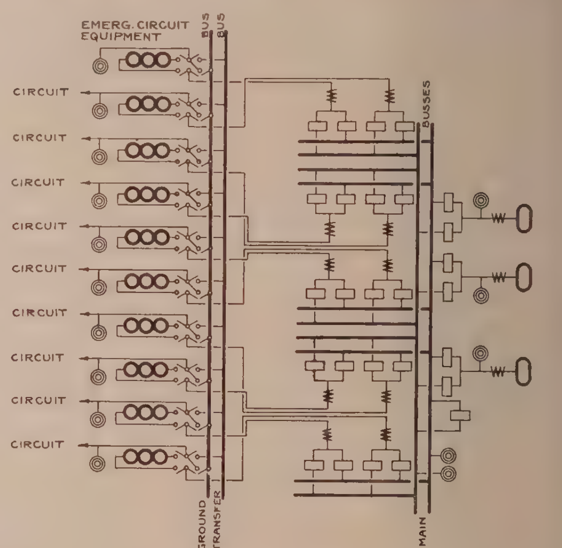


Fig. 11—A Line Diagram of 2300/4000-Volt Bus Connections

Fig. 12—2300/4000-Volt Switch Room in Substation

The 12,000-volt industrial loops are protected at the main substation by current-limiting reactors having a reactance of 1.2 ohms and by oil switches controlled by over-current induction type relays, with inverse time element. In addition to the protection, there are oil switches on the two terminals of the loop at each industrial substation, and each section of the loop between substations is protected by balanced relays, with the exception of the section marked *A*, Fig. 2, located in the central section of the loop. On this central

FIG. 13—TRANSFORMERS AND 2300/4000-VOLT REGULATORS IN SUBSTATION

section the balanced relays are replaced with power-directional relays, these relays being adjusted so that they will not open upon the reversal of the normal load upon one end of the loop should one of the substation

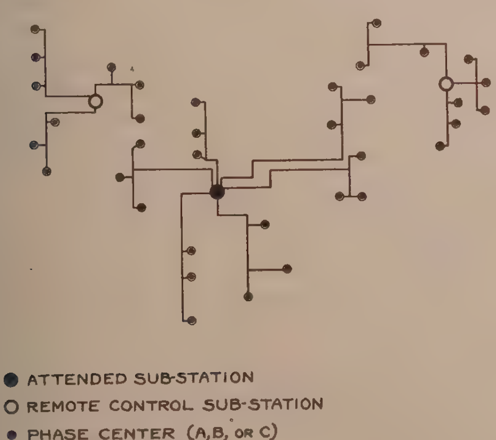


FIG. 14—TYPICAL DIAGRAM OF 2300/4000-VOLT FEEDERS

switches open, but having a setting which will open and disconnect one-half the loop in case of trouble which has failed to operate the balanced relays. This will allow the remaining half of the loop to continue in service. The directional relays also protect against a failure of section of cable between them.

A line diagram of the bus connections for a remote-controlled substation is shown in Fig. 5.

The 12,000-volt bus is divided into two sections and provided with disconnecting clips so that the two sections may be carried independently or in parallel upon one or both lines. Two transformers are installed between the 12,000- and 4000-volt busses, and disconnections are arranged upon these connections so that the transformers may be run in parallel or separately with the 4000-volt load divided between the transformers or entirely upon one of the transformers. Two exterior views of this type of substation are shown in Figs. 6 and 7.

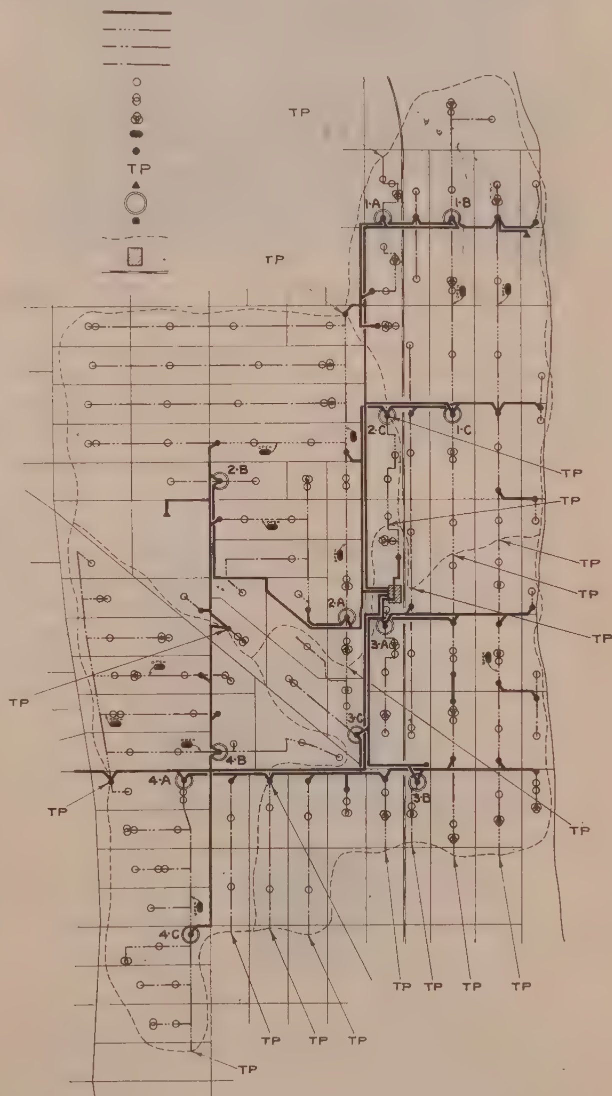


FIG. 15—ARRANGEMENT OF 2300/4000-VOLT CIRCUITS SHOWING TIE CONNECTIONS

A line diagram of the bus connections for an industrial substation is shown in Fig. 8, the two incoming lines being looped through the main bus and the transformers delivering energy to the customer arranged so that they may be fed from either one of the two lines, or from the loop. If either line opens the customer will receive

energy from the other line. The switch and transformer rooms for this type of substation are shown in Figs. 9 and 10.

A line diagram of bus conenctions for the 2300/4000-volt side of a substation is shown in Fig. 11. There are two main busses so arranged that a circuit may be fed from either of them. Disconnecting and grounding clips are provided so that any set of regulators may be taken out of service for repairs, the circuit being carried directly on the bus or through a spare set of regulators and the transfer bus. Each circuit is protected by an oil switch and an over-current relay with the setting adjusted to protect against short circuit.

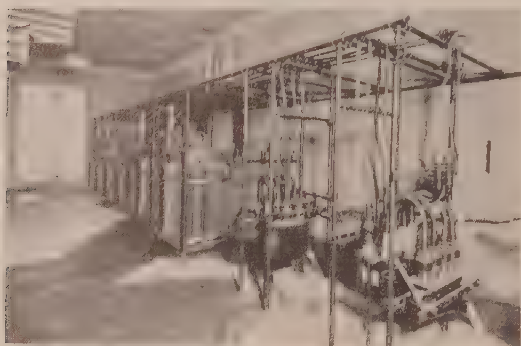


Fig. 16—View of 2300/4000-Volt Vault Showing Switching Terminal and Transformers

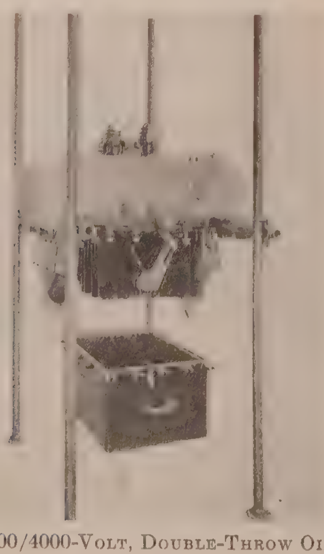


Fig. 17—2300/4000-Volt, Double-Throw Oil Switch

A typical diagram of 2300/4000-volt feeders radiating from a substation and its two dependent substations, is shown in Fig. 14. Feeders of these circuits are composed of four-conductor No. 0, lead-covered, copper cable, the *A*, *B* and *C* phase being regulated for various points upon the feeder so as to give an equitable distribution of voltage over the entire circuit. The switches and regulators for this type of substation are shown in Figs. 12 and 13.

The neutral points of the transmission systems are grounded at the generating stations and the neutral points of the 2300/4000-volt system are grounded at the various substations. The entire operation of the system is under the control of a load dispatcher. All distribution of load among stations, switch operation at stations and substations, and provisions for temporary service in case of line interruption, are carried out under his supervision.

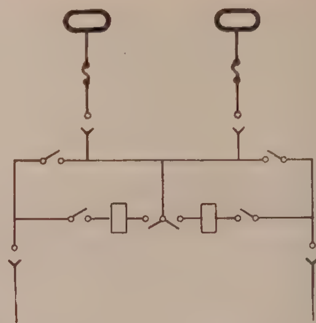


Fig. 18—Line Diagram of Bus Connections in 2300/4000-Volt Customer's Vault

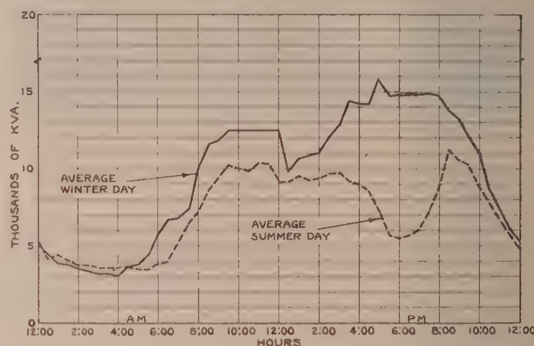


Fig. 19—A Typical Average Winter and Summer Day Load for a Substation

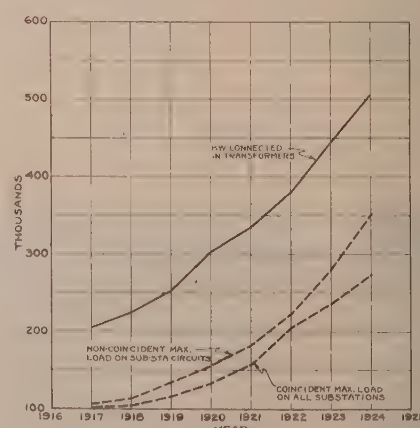


Fig. 20—Capacity Kilowatts of Transformers and Maximum Loads for the 2300/4000-Volt Distribution System

Under the system of distribution described, provision is made for reliability of service on the 2300/4000-volt busses by spare transmission lines and by spare transformer capacity, and likewise at the customer's industrial substations by loop lines. The 2300/4000-volt systems being radial, provision must be made upon the mains for emergency service in case of failure of one of the feeders. This emergency service is provided by installing ties between adjacent circuits either from the same substation or from adjacent substations. These tie points are provided with disconnecting potheads which may be closed or opened while energized, and in case of the failure of one circuit, the load upon this circuit is divided up and transferred to the surrounding circuits.

Fig. 15 shows the underground feeders and overhead mains for four circuits with the tie points between these circuits and adjacent circuits.

The entire system now comprises about 385 circuits of this type, having a rated winter capacity of 1200 kv-a. per circuit.

The current on the No. 0 underground cable was formerly limited to 150 amperes per phase, but experience has shown that, for this system, a winter load of 200 amperes per phase can be economically carried.

The circuit or line transformers vary in size from 5 to 150 kv-a. and are, in the majority of cases, installed upon poles and connected to the overhead mains.

Where facilities are not available to install 2300-volt transformers upon poles, these are placed in fireproof vaults on the customer's premises. Two independent sources of supply are usually brought into the customer's vault in lead cable from the underground system, and manually-operated oil switches are installed with the operating handles upon the outside of the vault. Upon the failure of the normal source of supply, the customer can, upon notifying the load dispatcher, transfer his load to the emergency line and thus restore service. These vaults are provided with ventilating ducts, lighting system, and sufficient space so that any one of the transformers may be replaced without disturbing the rest of the equipment.

A typical view of the interior of the 2300/4000-vault with the equipment is shown in Fig. 16. The switches shown in this cut consist of two separate single-pole, four-conductor oil switches manually interconnected, which have since been superseded by a four-pole, double-throw oil switch with disconnecting and switching device incorporated with it, as this gives more flexible operation and reduces the necessary space and the amount of equipment in the vault. An external view of this switch is shown in Fig. 17, and a line diagram of the connections in Fig. 18.

The cables are brought directly into the potheads on the sides of the switch, and disconnecting bars are provided at the top of the switch so that the load may be carried directly upon the cables and the switch disconnected for repairs or inspection. The 2300/4000-volt system on January 1, 1925, was serving 682,500 customers, there being connected to it 26,700 transformers of an average size of 19 kw. and 380,000 service connections to buildings.

A typical average winter and summer day-load for a substation is shown in Fig. 19, the difference between the 6 p. m. loads being due in part to daylight saving time and in part to the difference in hours of daylight.

The total connected line transformers, in kilowatts, the total noncoincident maximum on the 2300/4000-volt circuits and the coincident maximum for the entire 2300/4000-volt systems, for the years 1917 to 1924, are shown in Fig. 20.

The difference between Curves No. 1 and No. 2 and Curves No. 2 and No. 3, is due to the diversity between the residence, business and power loads upon the various transformers and circuits.

The rapid growth in load density in some sections of Chicago, will, in the near future, necessitate some modification of the present distribution system in these sections, either by the transfer of load to 12,000-volt loop circuits or by increasing the capacity of the present 2300/4000-volt circuits. If the heavily loaded districts are transferred from the 2300/4000-volt to the 12,000-volt system, the primary lines will have to be installed underground with the transformer installations in manholes or upon customers' premises. If the capacity of the present 2300/4000-volt circuit is increased, the voltage remaining the same, the distributing mains may remain above ground, and the circuits may continue to be worked upon while energized. The economic size of circuit for the present load density in these sections is in the neighborhood of 2000-kv-a., the feeder cables being composed of 350,000-cm. cable. Detailed studies of this problem are now being made to provide for the future growth of the system.

MERCURY CONTACT FLASHER FOR ELECTRIC WARNING SIGNALS

A new type of mercury contact flasher, designed for lighting devices for warning and controlling motor traffic has recently been put into service.

The mercury flasher consists essentially of a vacuum tube of special shape enclosing a steel plunger and a quantity of mercury.

When connected in an electrical circuit, the current flows through the operating coil and lamp. The current in the solenoid operates a plunger causing a difference in level of mercury between the two sections of the tube which alternately makes and breaks the current through the lamp.

The flasher is enclosed in a metal case, and may be mounted either in the base or in the casing of ornamental standards or mounted on wood poles and used with overhead fixtures. By rearranging the connections the flasher can be used as a relay for the control of street lighting circuits. The contacts are capable of breaking 30 amperes continually.

Distribution Practises in Southern California

BY R. E. CUNNINGHAM[1]

Associate, A. I. E. E.

THE conditions under which electric service is furnished in Southern California differ somewhat from other sections of the country. The pumping of water for irrigation has created a demand for electric power throughout the rural districts. Lines extended for that service have made electricity available for domestic purposes which, in themselves, would not have justified the extension of the lines. Records show that the electric development which has taken place under these conditions has resulted in a use of electric energy per capita per annum exceeding any other community in the United States, comparison being as follows:

Average for whole United States	450 Kw-hr.	per capita	per annum.	
Pennsylvania	520 "	"	"	"
New York	715 "	"	"	"
Washington	950 "	"	"	"
California	1280 "	"	"	"

In this same connection the per cent of farms which are supplied with electricity in various States is interesting:

The Province of Ontario	2.16	per cent
New York	3.5	per cent
Pennsylvania	4.5	per cent
California	3.5	per cent
Southern California	4.5	per cent

Analyses of rate schedules, both lighting and power, indicate that rates in Southern California, are approximately 35 per cent less than rates in eastern centers.

As the costs of distribution form a large part of the final charge to the consumer, the purpose of this paper will be to set forth, in general, the practises followed in the construction of the distribution system of the Southern California Edison Company, which, in some respects, differ from methods followed elsewhere and which it is felt are responsible to no small degree for the favorable rate charged for electric service in this territory.

SUBSTATIONS

Substations are supplied from a 60-kv. network and power distributed at 2.3, 4, 11 and 15 kv. according to amount of load to be delivered and the distances to be covered; in case of three large customers, service is given directly from the 60-kv. system. The construction of substations, as well as the equipment installed for service to customers, has been simplified and in general consists of little more than the necessary transformers with the protective devices. Substations, except in metropolitan districts, are of the outdoor type with housing provided for the instruments and control equipment for the more important stations.

Fig. 1 illustrates a roadside, pole-top substation, stepping down from 15 kv. to 4 kv. with 150 kw. capacity.

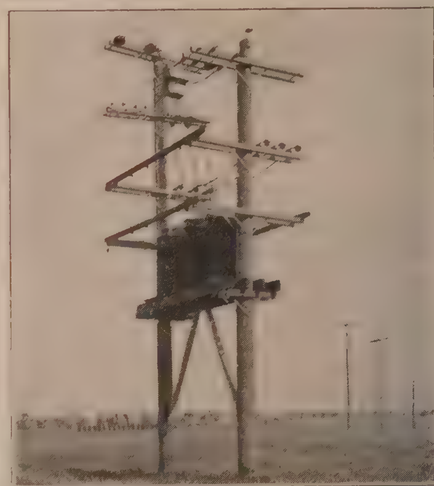


FIG. 1 ROADSIDE, POLE-TOP SUBSTATION

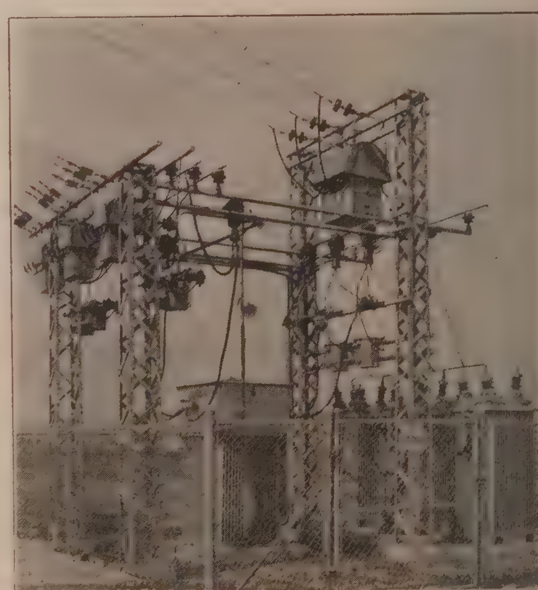


FIG. 2 FIFTEEN 2.3-KV., OUTDOOR SUBSTATION

An automatic oil switch protects the high voltage side of the transformers. Where greater capacity is required, construction similar to that shown in Fig. 2 is used. This style of construction lends itself to capacities up to 1500 kw. Note the outdoor type instrument

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Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash. Sept. 15-19, 1925.

transformers; also the outdoor, three-phase, induction type regulator. In this case, transformation is from 15 kv. to 2.3 kv. However, provision is made for changing to 4 kv. as soon as desired.

Regulators are so designed as to permit operation either at 2.3-kv. delta or 4-kv. star. It has been the practise of this company to use three-phase regulators exclusively. The first cost per kw. of such equipment is no more than for the same capacity in single-phase regulators, with a saving in floor space, wiring, and maintenance of auxiliary equipment. There is at present in service on this system some 212 three-phase regulators, distributed among 95 substations, with aggregate circuit capacity of 195,000 kv-a. These regulators are used on 2.3- 4-kv. and 11-kv. circuits. Where the character of the load supplied by any given substation is similar, a regulator capable of handling the entire output of the transformers is used. Where various circuits supplied by the substation are of different characteristics as regards length of line, time

Fig. 3—Sixty 11-Kv. Outdoor Substation

and amount of peak load, regulators are installed on each individual circuit.

Fig. 3 illustrates an outdoor substation, 60 kv. to 11 kv., of 4500-kw. capacity, with outdoor 11-kv. regulator controlling the total output of the transformers.

Distribution Lines

In general, good substantial line construction has been used, the first cost possibly being higher than lighter construction but proving to be less expensive after a long term of years. Only butt-treated poles have been set since year 1914. Line wires are No. 6 size or larger according to load to be carried.

Fig. 4 represents the more usual type of line construction where only one primary and one secondary circuit is to be carried. California State law controlling line construction, requires a separation of 4 ft. where wires of voltage higher than 600 volts are placed above wires carrying less than 600 volts. As an alternative, the law permits the wires to be placed on the same crossarm if a horizontal separation of three feet is provided. By placing primary wires at one end of the crossarm and the secondary wires at the other end of the same arm, it is possible to use a pole of practically five feet less, over-all length, than would be necessary if primary wires were placed above the secondary wires. Also, it is felt that safer construction is provided in that the primary wires may not, if they should fall, come in

Fig. 4—Single-Phase, One-Arm Construction

contact with secondary wires. Transformers supplying lighting service are never connected in parallel on their low voltage side but are connected consecutively across the various phases of the primary circuit so as to maintain as nearly as possible a balanced load on the three-phase lines locally, as well as the total at the substation.

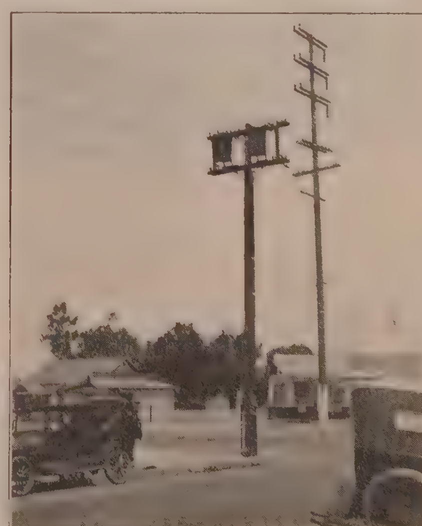

Fig. 5—Pole-Mounted Street Light Regulators

Where street lighting service is required the series system is used both for bracket fixtures and span construction; also ornamental standards. Pole-top

constant-current regulators, as shown in Fig. 5, are supplied from a special primary circuit controlled at the substations, where a number of units are to be used, or controlled by a time switch connected to the local commercial primary line when only a single regulator is in service.

In urban districts the 2.3-kv., three-phase system had been used to furnish commercial lighting and small power. These lines are now being changed over to 4-kv., four-wire. A common neutral wire is used for all circuits from a given substation and connected directly to the neutral of the station transformers without passing through the circuit switches. The general practise is to carry the three-phase well out to the end of all branch lines so as to obtain the full advantage of three-phase transmission at 4 kv. and insure a balanced load.

In rural districts, and for irrigation, service is rendered from 11 kv. lines. Large industrial loads are served from 15 kv. lines.

Use of Three-Phase Transformers

A very general use has been made of three-phase transformers on 11-kv. and 15-kv. lines in sizes 10 to 100 kw. These three-phase transformers are of two general designs, as shown by diagrams, Fig. 6. Both types have their high voltage windings, star connected, ungrounded, but with variable taps on the neutral connection. This permits changing of taps by moving of one common bar, and eliminates possibility of error in changing taps. A very usual condition in the irrigating districts requires service to a small pumping

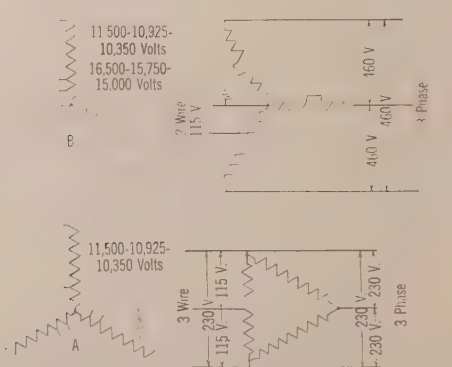

Fig. 6—Connection Diagram Three-Phase Transformers
B. Star-to-star A. Star-to-delta

plant in the owners backyard and service for light and heat in the house. For such service, transformers have a delta, low-voltage winding, furnishing voltage of 230, three-phase for power, (Fig. 6A.) At the same time, by tapping the center of one-phase winding, a three-wire, 115/230-volt service can be had. One manufacturer's description of this transformer is as follows:

"These transformers are specially designed to carry both single-phase and three-phase loads at the same time, the single-phase load being taken off of the middle leg. These transformers are designed to carry two-thirds of kv-a. rating at three-phase and one-third of kv-a. rating at single-phase. The three-phase load is divided equally on all three legs while two-thirds of single-phase load is carried by one leg and one-third by the other two legs in series. The resultant current in any leg is then equal to the single-phase current as indicated above combined with the three-phase 'Power' load or current in its proper relation. The design of the transformer is such as to take care of

Fig. 7—Three-Phase Transformer Furnishing Light, Heat and Power

maximum current in any of the three legs due to phase relation of one-phase current and three-phase current, or will take care of load as indicated when one-phase load is in phase with any one of the three-phase. The middle leg has no additional reinforcing over the other two legs. Taking the 15-kv-a. size as an example, with full load on the transformer (10-kv-a., three-phase and five-kv-a., one-phase) at unity power factor, the neutral shift of the high voltage will be 2.3 per cent."

Another manufacturer has provided additional copper in the single-phase leg over either of the other two legs as follows:

10 kv-a.	25	per cent
15 kv-a.	10	per cent
25 kv-a.	35	per cent

These transformers are used in sizes 10, 15 and 25 kw. Fig. 7 shows a three-phase transformer of this type, supplying three-phase power to motor in the pump house and a three-wire heat and light service.

In the larger pumping plants a 440-volt motor is generally desired and for such service a transformer with a star-connected, low-voltage winding is used with two coils per phase so that either 230 or 460 volts, three-phase may be obtained, Fig. 6B. The neutral con-

nection is brought out of the transformer permitting grounding. With 460 volts between phases, there is only 265 volts from any phase wire to ground. At the same time there is also brought out a tap from one coil at 115 volts above the neutral from which a limited supply of lighting can be obtained for the illumination of the pump house. This type of transformer is used in sizes from 10 to 100 kw.

Fig. 8—Three-Phase Power Transformer

Fig. 8 is a typical installation of this type of transformer. Note the high voltage connections to the transformer are brought in to the front of the case well away from the pole and crossarms. The transformer is protected by a pole-top, automatic oil switch. This switch is equipped with a series trip-coil in each line adjusted to the capacity of the transformer. Trouble across any phase or between any phase wire and ground will cause the switch to open and disconnect the transformer entirely from the line. The switch is operated by pull cables from the ground. In case of overload, causing switch to operate, the customer can, himself, restore the service and save the loss of time as well as the expense of troublemen from the Company's District Headquarters going out to take care of the trouble which would be the condition were fuses used for protection. This type of switch is used on all larger installations or where important service is rendered at considerable distance from district headquarters. Such a switch also permits of disconnecting the transformer from the line when it is not in service and thus saves core loss. It has been found that where a convenient means of this sort is provided, the customer is willing to cooperate with the company in this respect. The use of this switch has eliminated the frequent cases of motor and transformer burn-outs due to single-phasing caused by the blowing of one primary fuse. The company has installed on its system some 2100 switches of this type.

Fig. 9—Three-Phase Auto-Transformer

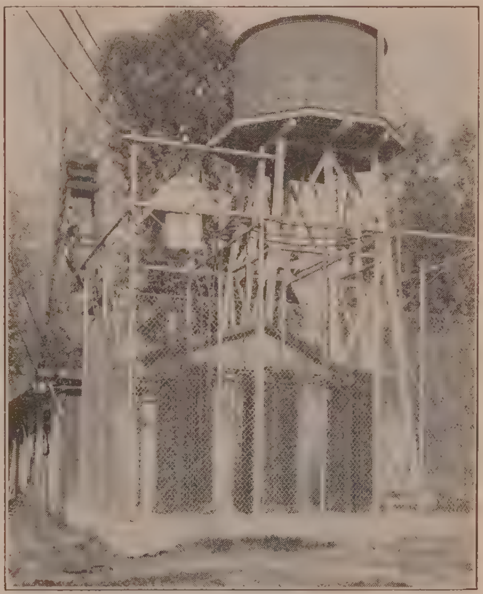

Fig. 10—Three Single-Phase Units Furnishing Power

In addition to the two types of three-phase transformers described above, some use has been made of the standard three-phase unit having a high-voltage winding for 2.3- or 4-kv. and a low winding of 230 or 460 volts. These transformers are expecially convenient in locations where lines are in the process of being changed from 2.3- to 4-kv. In many cases, 2300-volt motors have been connected direct to distribution circuits of that voltage. When these circuits are changed to 4-kv., a three-phase, 2.3- to 4-kv., auto-transformer has proved to be an inexpensive, convenient and entirely satisfactory means of supplying such motors from

four-wire, 4-kv. lines without changing the motor. (See Fig. 9.) At this time the company has a total of 2048 three-phase transformers of the above described types on its lines, aggregating 66,715-kw. capacity.

Larger Power Installations

On larger power installations, transformers are placed on the ground and enclosed with suitable guards. Fig. 10 is an installation of three 200-kw., single-phase transformers 15-kv. to 460 volts, supplying power to pumping plant. In cases of this sort, the customer is asked to provide the concrete foundation, the Company furnishing and installing the electrical equipment and guards.

A general practise is to so arrange distribution circuits that they may be operated as a network by sectionalizing with pole tops-witches. This permits the taking out of service of smaller sections of lines without interrupting completely service throughout the territory. However, in case of very important customers, arrangements are made for double service. Fig. 11 represents such a condition, utilizing pole-top, double-throw air break switch, controlled by operating lever at the base of the pole. In case service is cut off from one direction, the customer can throw the switch to the other circuit and so immediately restore operation.

Fig. 11—Double Service from 15-kv. Lines

Fig. 12 illustrates an installation of three 3000-kw. transformers with one spare, taking power from two 60-kv. lines and furnishing service at 2.3-kv. to cement plant. The two incoming 60-kv. lines are controlled by oil switches which can be seen back of the transformers. Here again may be noticed the simplicity of the installation even though connected to the higher voltage lines and supplying a fairly large block of power, it consists of little more than transformers and protective device

In conclusion, it should be stated that the methods above described are not expected to guarantee absolutely 100 per cent service, still results obtained have been so near to 100 per cent that it is felt any further expenditures on the distribution lines and equipment would not be justified.

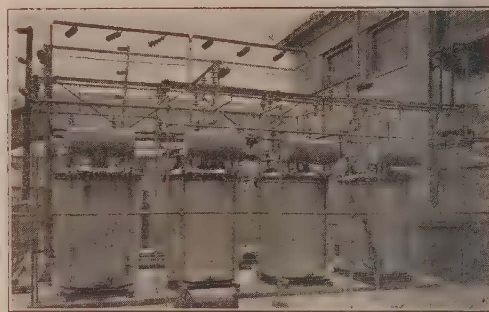

Fig. 12—60-kv. Service to Cement Plant

Fig. 13—Oranges, Oil and Electric Power

As a closing picture of characteristic conditions in Southern California, note Fig. 13. Here is shown the principal industries, including agriculture, oil and the line crew finishing an installation for electric power service.

LARGEST ARTIFICIAL LAKE IS BEING BUILT

At Cherokee Bluffs, one of the most isolated places of Alabama, an artificial lake, which will have a shoreline 700 miles long and cover 40,000 acres of land, is being built. When completed in 1926 it will provide water to drive three 45,000 horse power electric generators.

Distribution Line Practise of the San Joaquin Light and Power Corporation

BY L. J. MOORE[1] and H. H. MINOR[1]
Associate, A. I. E. E. Non-Member

Synopsis.—*General description of practise of the San Joaquin Light & Power Corporation in serving rural distribution. Describes an 11,500-volt fuse manufactured by the company, shows standard transformer sizes used for serving combination loads and describes methods of hot wire maintenance used, together with data on savings accomplished by the use of hot wire tools.*

General

THE distribution system of the San Joaquin Light & Power Corporation serves a wide territory in which are located a number of cities, but none of them very large. Fresno is the largest, having a population of about 70,000; Bakersfield is next with a population of 25,000, while the other cities and towns in the territory are relatively small. The agricultural development in the territory served is rapidly going forward, and on account of the fact that a large part of the irrigation of the San Joaquin Valley is by electric pumping, the company has a large mileage of distribution lines serving rural districts. The following table gives an idea of the magnitude of the rural load served by the company:

SAN JOAQUIN LIGHT & POWER CORPORATION AGRICULTURAL SERVICE YEAR ENDING 12-31-24

	No. of Consumers	Kw-Hr. Consumption
Rural Pumping Plants	6,064	142,800,971
Rural Heating & Cooking and small power	1,036	4,214,699
Rural Domestic Lighting	9,977	3,377,347
Total	17,077	150,393,017
System Total	58,126	382,175,102
Per cent of System Total	29.3 per cent	39.3 per cent

The total area served comprises approximately 25,000 sq. mi. The company has around 5000 miles of transmission and distribution lines. From the above data it may be seen that the system of the Company is distinctive in the great mileage of lines for the total number of consumers served.

Voltage and Type of Distribution System

All of the rural distribution system and the distribution in the larger of the smaller towns is 11,500-volt, three-phase, three-wire. The lines were originally 11,500-volt, three-phase, four-wire, with the neutral solidly grounded at the station and at occasional intervals along the lines. The distribution transformers serving three-phase power were rated at 6600 volts on the primary side and star-connected for 11,500 volts. The secondaries were connected in delta. Single-phase load was served by a single transformer connected between one-phase wire and neutral, or in some cases by installing one transformer larger than the others in the power bank and taking the single-phase load from that side of the delta-connected secondary. Considerable trouble was experienced with the four-wire, three-phase system, on account of numerous transformer burn-outs, due to one primary fuse blowing and operation continuing on open-star. The solution of this difficulty was finally found in the use of 6600-volt transformers, designed for 23,000-volt test voltage and

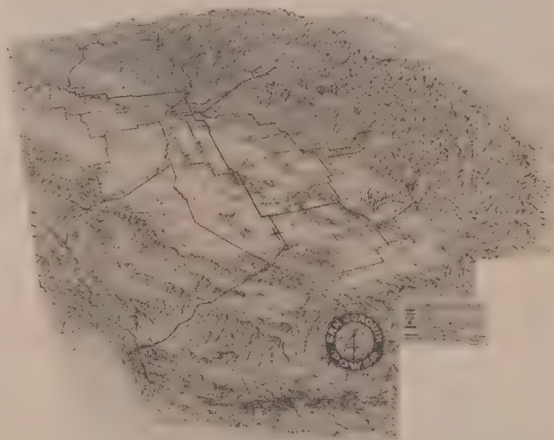

Fig. 1—The San Joaquin Light and Power Corporation System

the removal of the neutral wire and all primary neutral grounds on the distribution transformer banks. Single-phase loads were served by 11,500-volt transformers connected between line wires. One main consideration in deciding to use a bank for the motors and an individual transformer for the single-phase load was that the rates for agricultural power in force at the time provided for summer use only. Motors in that service were sealed up during off season months and fuses removed from power transformers. The lighting-service transformer was still left in service. In this way core losses were reduced in the winter months, and the 11,500-volt, three-phase, three-wire distribution system came

1. Both of the San Joaquin Light & Power Corp., Fresno, Calif.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

into use with 6600-volt transformers and with neutrals grounded at substations only.

It is recognized that four-wire, three-phase distribution is in use in many cities and is operating with satisfactory results. In city distribution, however, transformer banks almost always serve a number of motors and the starting current of any one motor is usually not large enough to overload the transformers. In rural distribution, as in the case under consideration, usually only one motor is served from a bank and fuses

Fig. 2—An Agricultural Installation

on the transformers large enough to provide for the motor starting current provide no overload protection for the transformers. Therefore, the motor and transformers might operate with one transformer fuse blown without the other fuses going out. In this manner, we would have open-star operation on the primary and an overload on the two transformers still in service sufficient to burn them up without blowing the fuses. Single-phase operation, however, which would occur if the neutral of transformer banks were not grounded or connected to the fourth wire, is sufficient to blow the fuses, and the transformers are removed from the line before any burnout could occur.

Loading of the District

The entire territory is in the light-loading district as set up by the National Electric Code. The loading, as specified by this code, is not necessarily followed in California because of the fact that loadings and factors of safety are all provided for in the California code, otherwise known as General Order No. 64 of the California Railroad Commission. In more than thirty years of record in the San Joaquin Valley, the maximum wind-loading recorded has been 4½ lb. per sq. ft. Snow and sleet are not encountered except in a few instances where the lines run up into the mountains reaching elevations of 3000 ft. or more. It is, therefore, seen that very light line construction may be used with safety. The California code requires lines to be designed for a minimum of 6 lb. per sq. ft. wind pressure with no ice load. Prior to the issuance of this code, the San Joaquin Light & Power Corporation had pulled distribution lines up to a tension which provided for a wind pressure of 4½ lb. per sq. ft. with no ice loading, and a minimum temperature of 20 deg. above zero fahr. This permitted the use of relatively short poles and small sags in the conductors. No difficulty was experienced with this construction, but since the issuance of General Order No. 64, the loading of 6 lb. per sq. ft., specified therein, has been used.

Poles

The company uses western red cedar poles exclusively. Experimentally, some native poles have been tried out but the results have not been sufficiently satisfactory to justify their use so long as the western red cedar poles can be obtained. All poles are butt-creosoted by the open tank method, the company maintaining its own treating plant at Fresno. Past experience has shown that one of the fundamentals in treating poles is proper seasoning. Some of the earlier experiments carried on by the Government on pole treating were on the system of the San Joaquin Light Power Corporation, and the Company has benefitted by the experience gained in those experiments. The pole-treating plant is on a forty acre tract of land in the outskirts of Fresno, where adequate storage facilities are provided. The Company's practise is to purchase poles from the North Pacific states during the summer and fall of one year for use during the following year; in this manner the poles are shipped untreated to

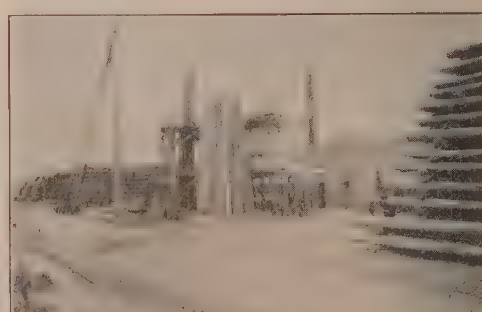

Fig. 3—Pole-Testing Plant

Fresno and allowed to remain in the yards during the winter, spring, and summer months, until needed, when they are treated. In this manner adequate seasoning is obtained. Facilities for handling them are provided so that they may be taken from the piles, creosoted, and loaded directly on to the cars for shipment to the various districts.

Because of low wind pressures and lack of snow and ice in the territory, this Company has been able to use

lighter poles than has been the practise in the heavier loading districts. Heavy, Class *A* poles are not used except at corners and for hanging transformers.

Spans and Conductors

It has been the policy of the company to use relatively long spans in its distribution work. This has resulted in distribution lines of low cost, a feature which has been very necessary in the development of the widely scattered load which the Company serves. On account of the light wind pressures encountered, these long spans have been satisfactory and have caused no trouble. The standard distribution line span used is 330 ft. for rural distribution. In city work, of course, shorter spans are necessary.

Medium hard drawn copper has been used almost exclusively for conductors. Before the issuance of General Order No. 64 by the California Railroad Commission, the company uses a loading of 4½ lb. per sq. ft. with no ice figured for conductors up to No. 2 B & S gage. This resulted in very small sags and allowed the use of 30-ft. poles along highways, giving a clearance of

Fig. 4—Crossarm Boring Machine

about 22½ ft. in the center of the spans. General Order No. 64 has required greater clearances and the use of 6-lb. wind pressure has required greater sags. The standard pole for this work is now a 35-ft. minimum.

Crossarms

For a great many years the Company has manufactured its own crossarms. They are made from four by six, Douglas fir, surfaced on four sides. A crossarm mill is in operation in which is installed a gang boring machine, boring all holes in one operation. Until recently crossarms were painted but this practise has now been discontinued. The requirements of General Order No. 64 are that all *primary* arms be either painted a bright yellow or that a sign reading "High Voltage" be installed. But it was found difficult to maintain the painted arms so that the color should be readily distinguishable for more than two years. The cost of repainting was far in excess of the installation of high-voltage signs; so as experience had also shown that the life of the arm was not materially increased by painting, it was decided to "sign" all arms for use on primary lines and discontinue the painting altogether.

11,500-Volt Fuses

An inexpensive form of fuse for use on 11,500-volt lines was developed by the San Joaquin Light & Power Corporation many years ago. It originally consisted of two L-shaped iron pins, bolted through the side of a crossarm. To these pins was cemented a standard

Fig. 5—Crossarm Mill

line insulator to which was attached a cast iron cap, carrying contacts. Two of these contact insulators were used with each fuse. The "fuse cross" part was made of treated hard wood, one by one by eighteen inches. It carried a 16-inch porcelain tube, through which the fuse wire was threaded. Brass blades were attached to each end to fit the contacts, and at the center of the wood cross part an insulator was attached to facilitate handling by means of a fuse stick. This equipment has

Fig. 6—Old Style 11-Kv. Fuse

recently been modified to still further cheapen the installation. Standard metal pins are now used instead of the L pin. The insulator is screwed on this pin and a brass clamp with projection carrying the fuse contacts is used. The cross part remains the same, except that the insulator has been removed and a fuse puller to grip the wood part instead has been developed. A further development is contemplated where a bakelite tube will be substituted for both the wood part and

the porcelain tube now used. Cuts of both the old and the new device are shown herewith.

An interesting feature of these fuses is the method of fastening the fuse wire to the blades. Through a cork is inserted a short piece of No. 18 copper wire. The fuse wire is fastened to the inner end of this copper wire and the other end is clamped under a screw on the blade.

Fig. 7—New Style 11-Kv. Fuse

The cork is inserted in the ends of the porcelain tube, so that the fuse wire is not exposed. When the corks have been omitted, considerable trouble has been experienced by birds breaking the fuse wire; they seem to have a liking for bright wire, and have been found by

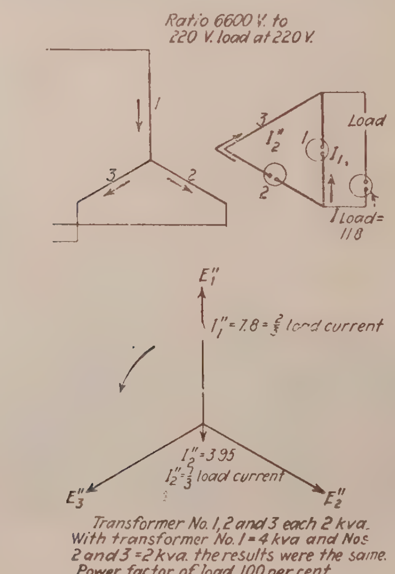

Fig. 8

trouble shooters, with a section of the fuse still clamped in their beaks.

Service to Three-phase and Single-phase Load in Rural Distribution

Many rural installations involve three-phase power for operating irrigation pumps and single-phase power for lighting, heating and cooking and some small single-phase motors. The Company's standard method of serving such installation is to combine the loads and serve

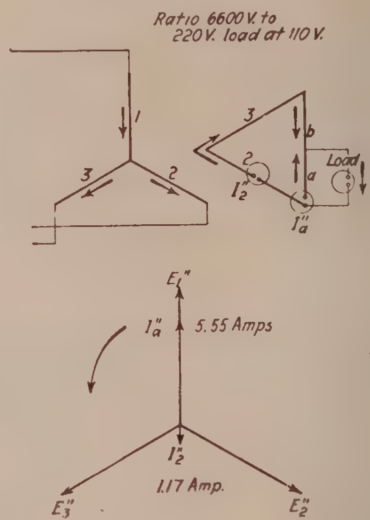

Fig. 9

them from one common three-phase bank of transformers. This has been found to be very much cheaper than setting a three-phase bank of transformers for the pump-

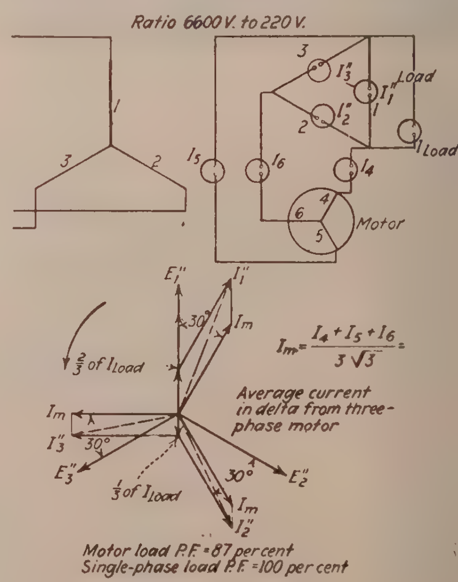

Fig. 10

ing plant and a 11,500-volt, single-phase transformer for the single-phase load. Figs. 8, 9 and 10, with their explanations, show the results of actual tests without taking

into account magnetizing currents on the transformers. These magnetizing currents are so small that they may be neglected so far as the load on the transformers is concerned, but it has been found that the diversity factor between the loads connected is so great that the added capacity in the transformer connected to the single-phase load can be made much smaller than

transformer connected star-delta with the star isolated from the ground, trouble would undoubtedly be caused. Also if the 25-kv-a. transformer were loaded up with a single-phase load, the coils of the two 5-kv-a. transformers would be overloaded sufficiently to burn out, and the neutral would shift so badly that very unsatisfactory voltage would result.

TABLE I—TRANSFORMER LOADING TABLE

Single Phase Demand Kv-a. 110 v.	Single Phase Demand Kv-a. 220 v.	3 Phase Load	Transformer Sizes 6900 to 115-230
0.88	1.76	2 H. P. Motor	1½–1½–1½
2.3	3.5		1½–3 –1½
2.3	4.6		3 –3 –3
3.8	7.6		3 –5 –3
6.0	9.2		3 –7½–3
6.0	12.0		5 –7½–5
8.1	15.2		5 –10 –5
8.1	16.2		7½–10 –7½
12.3	23.9		7½–15 –7½
12.5	24.9		10 –15 –10
0.6	1.2	3 H. P. Motor	1½–1½–1½
2.0	2.6		1½–3 –1½
2.0	4.0		3 –3 –3
3.55	7.1		3 –5 –3
5.7	8.0		3 –7½–3
5.7	11.4		5 –7½–5
7.9	14.2		5 –10 –5
7.9	15.8		7½–10 –7½
12.2	22.8		7½–15 –7½
12.2	24.4		10 –15 –10
20.8	31.4		10 –25 –10
0.0	0.0	5 H. P. Motor	1½–1½–1½
0.5	1.0		1½–3 –1½
1.5	3.0		3 –3 –3
2.9	5.8		3 –5 –3
3.0	6.0		5 –5 –5
5.2	10.4		5 –7½–5
7.4	12.0		5 –10 –5
7.4	14.7		7½–10 –7½
11.7	20.6		7½–15 –7½
11.7	23.4		10 –15 –10
20.3	29.5		10 –25 –10

Single Phase Demand Kv-a. 110 v.	Single Phase Demand Kv-a. 220 v.	3 Phase Load	Transformer sizes 6900 to 115-230
0.8	1.6	7½ H. P. Motor	3 –3 –3
2.3	3.2		3 –5 –3
2.3	4.7		5 –5 –5
4.7	9.4		5 –7½–5
6.75	13.5		7½–10 –7½
11.1	18.4		7½–15 –7½
11.1	22.1		10 –15 –10
19.2	27.0		10 –25 –10
19.2	38.4		15 –25 –15
30.5	44.2		15 –37½–15
0.0	0.0	10 H. P. Motor	3 – 3 –3
0.6	1.0		3 – 5 –3
1.6	3.2		5 – 5 –5
3.9	6.4		5 –7½–5
3.9	7.8		7½–7½–7½
6.1	12.2		7½–10 –7½
10.5	15.6		7½–15 –7½
10.5	21.0		10 –15 –10
19.1	24.5		10 –25 –10
19.1	25.5		15 –25 –15
29,9	42.0		15 –37½–15
0.5	1.0	15 H. P. Motor	5 – 5 –5
1.85	1.85		5 –7½ –5
2.8	5.6		7½–7½ –7½
5.0	10.0		7½–10 –7½
5.6	11.2		7½–15 –7½
9.4	18.8		10 –15 –10
18.0	20.0		10 –25 –10
18.0	36.0		15 –25 –15
28.8	37.6		15 –37½–15
28.8	57.6		25 –37½–25
	72.4		25 –50 –25

Single Phase Demand Kv-a. 110 v.	Single Phase Demand Kv-a. 220 v.	3 Phase Load	Transformer Sizes 6900 to 115-230
1.37	2.75	20 H. P. Motor	7½–7½–7½
3.7	5.50		7½–10 –7½
3.7	7.4		10 –10 –10
8.1	14.7		10 –15 –10
8.1	16.2		15 –15 –15
16.8	32.4		15 –25 –15
16.8	33.6		25 –25 –25
27.6	55.0		25 –37½–25
	67.4		25 –50 –25
0.0	0.0	25 H. P. Motor	7½– 7½–7½
3.0	6.0		01– 10– 10
7.5	12.0		10 –15 –10
7.5	15.0		15 –15 –15
16.2	30.0		15 –25 –15
16.2	32.4		25 –25 –25
27.0	54.0		25 –37½–25
	65.0		25 –50 –25
1.0	2.1	30 H. P. Motor	10 –10 –10
2.1	4.2		10 –15 –10
6.65	13.3		15 –15 –15
14.52	22.6		15 –25 –15
14.52	29.0		15 –25 –15
25.7	51.4		25 –37½–25
	58.2		25 –50 –25
2.85	5.7	40 H. P. Motor	15– 15 –15
11.88	11.4		15 –25 –15
11.88	23.8		25 –25 –25
22.9	45.8		25 –37½–25
	47.6		25 –50 –25
.9	1.8	50 H. P. Motor	15 –15 –15
3.8	3.8		15 –25 –15
10.2	20.4		25 –25 –25
21.2	40.8		25 –37½–25
21.2	42.4		37½–37½–37½
	6.2		37½–50 –37½

The Demands shown in the first two columns of each group of this table are the Maximum Single-Phase Demands that should be connected to Transformer Banks shown in Column 4 while serving the motors shown in Column 3. The first Column is the Single-Phase Demand available for two wire 110 volt service and the second Column is that available for 220 volt two-wire or 110/220-volt three-wire service.

The Single-Phase Demand shall be computed as follows when actual measurements cannot be made.

No. of Consumers	Character of Load	Demand % Connected
1	Lighting Only.........	50%
2 or 3	" "	40%
4 to 5	" "	25%
Over 8	" "	15%
1	Heating & Cooking.	75%
2 or 3	If Air Heaters are in-	50%
4 or 5	cluded in these loads	40%
6 to 8	Demand = 75% Air	30%
Over 8	Heaters + Demand for Balance.	20%

Single-Phase Motors 100 per cent

Note: These values assume that the motors are not overloaded.

The Single-Phase Demands are on average demand of 1 Hour (not 15 min. Max. Demand.)

would be possible were this load served from a single-phase transformer, separate from the power bank. A table showing the Company's standard practise of service to this class of load is included in this article.

It is well to remember in such installations that it is not possible to bank together transformers of too great a difference in size. For instance, if two 5-kv-a. transformers were banked together with one 25-kv-a.

Hot Wire Maintenance of Distribution Lines

In 1923 the San Joaquin Light & Power Corporation was confronted with the problem of changing a great number of 11,500-volt "dead end" insulators which had proven faulty and were fast failing. As these insulators were installed generally on the 11,500-volt lines of the Company, to have killed the lines, even though they were in large part loops with sectionalizing switches installed, would have meant an immense loss of revenue

and good will because of the interruptions necessitated by so doing. These were cap and hook insulators lending themselves readily to replacement with units of a similar type.

It was decided that with the proper tools, this work could be performed "hot," and such tools were developed by San Joaquin employees, several thousand of these insulators having been replaced with them. The success of this operation led to further development of hot wire tools until complete equipment with which almost any job can be done on a hot line without any great

Fig. 11—Applying Wire Grip to Hot Line

Fig. 12—Replacing a "Dead-End" Insulator, Hot

hazard to the workmen is now available. The truth of this statement is proven by the fact that in eighteen months' use on the San Joaquin System there has not been a single accident.

In each of the fifteen districts of the system, a "hot wire wagon" is maintained. A Dodge commercial is used, it being equipped with a box for tools and facilities for carrying replacement equipment. The crew

Fig. 13—Tying a Pin-Type Insulator, Hot

Fig. 14—Working a Hot Line through a Lower Circuit

consists of two linemen, both schooled in the use of the hot tools, and a groundman. This crew performs all *hot* work in the district and, in addition, makes periodic patrols of important distribution lines and special patrols of any line which has shown a fault. Necessary or advisable repair work is also done when found. This includes the replacement of the dead-end insulators mentioned above, the replacing of broken pin-type insulators, installing new crossarms in place of ones burned, etc. By these repairs many failures of lines and consequent interruptions to service are saved.

Shut-downs are no longer necessary in order to cut in for a new extension. Temporary "hook jumpers" are connected by the line crews and the "hot wire crew" is notified. At the first opportunity this temporary connection is made permanent. Should the work require a new pole in a hot line, the pole is set and the hot line is transferred to it by the hot wire crew, all without an interruption. In the same manner new poles are set to replace burned or broken poles.

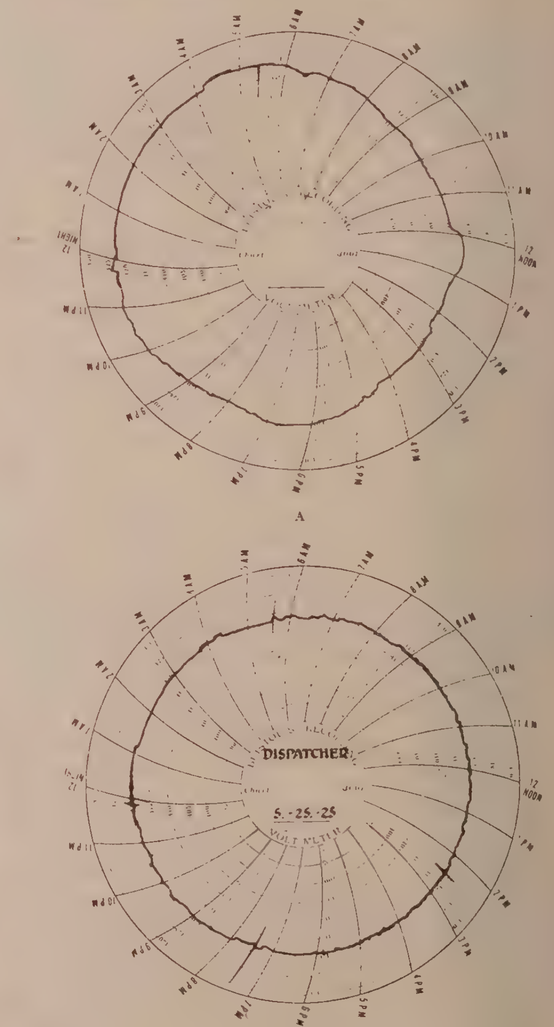

Fig. 15—a Untriagulated Bus Voltage at Substation
b Regulated Voltage at Load Center

The adoption of these hot wire maintenance methods has not only solved the problem of the dead-end changes, but has resulted in a saving of time and mileage in the regular repair jobs. Much of such work was performed at night or on Sunday in order to inconvenience the consumer as little as possible. That meant overtime and often slow work on account of poor light. Much time was consumed in the travel necessary to operate sectionalizing switches. While this saving is considerable and well worth while, it is not to be compared with the money saving and benefit derived from the service interruptions that are obviated thereby.

TABLE II
HOT WIRE TOOL REPORT
San Joaquin Light & Power Corporation January 1, 1925 to March 31, 1925.

District	Work Performed Using Hot Wire Tools								Requirements if Same Work were Performed Without Hot Wire Tools			
	Dead end Insulators replaced.	Broken Pin Type Insulators replaced.	Broken Fuse Contact Insulators replaced.	Broken or rotted Pins replcead.	Jumpers made permanent.	New poles tied in line.	Crew hours to perform work.	Miles driven to perform work.	Transformer Banks out of Service.	Sectionalizing Switches to operate.	Crew hours to do work.	Miles driven to do work.
Madera	42	10		3	158	11	122	1445	1108	197	202	2014
Fresno	159	43	24	29	382	32	464	2490	2077	765	636	4307
Selma	38	17	5	2	206	48	231	1689	3577	310	431	3160
Merced	387	54	9	19	146	7	207	1455	1484	261	318	2555
San Joaquin	156	16		1	58	3	51	504	1110	101	69	853
Dinuba	148	3			99	7	115	711	1120	180	136	1170
Corcoran	353	43		2	85	23	142	933	2282	178	196	2541
TOTALS	1283	186	38	56	1134	131	1332	9237	12,758	1992	1988	16,600

82 Crew days saved @ $18.50 =	$1437.00	1332	9237
6363 Miles saved @ $ 0.06 =	$ 381.78		
		656	6363
Saving in labor and mileage	$1818.78		

A tabulation of reports received from several of the hot wire crews is included herewith. The report shows only the additional time and mileage that would have been consumed by switching out the sections upon which work was being done. No attempt has been made to include overtime, etc. that might have been necessary. "The transformer banks out of service" is from an actual count from the district maps of the banks on the section of line worked on.

Unique Automatic Regulator Installation in the City of Fresno

In the distribution system for the City of Fresno a rather unusual regulator scheme has been in use for two years. The distribution is 2300-volt, all overhead. Two 500,000-cm. feeders cross the main alleys of the business district at a distance of five blocks apart. Three other feeders of 4/0 wire each tap an alley primary of the same size at a point midway between the 500,000 cm. lines. These alley primaries are connected to these heavy lines through automatic pole top oil circuit breakers set for instantaneous trip. The smaller individual alley feeders are connected directly to the two-kilovolt bus at the substation through the usual automatic circuit breakers. The 500,000 cm. feeders are also connected to this bus but each have two-single-phase induction regulators installed and their circuit breakers are set to trip later than the smaller feeders. Thus there is in effect a net work consisting of five interconnected feeders from one bus with automatic regulators in two of these feeders only.

The compensators of these regulators are set to maintain voltage at a point near the center of load. Thus bus voltage fluctuation so changes the load on the several feeders that they automatically regulate the voltage through line drop. Extreme fluctuation at the substation could cause a circulating current to be set up, but this is cared for by opening the three small feeders at the substation and, if necessary, by allowing the big feeders to operate over-loaded for a short time. No

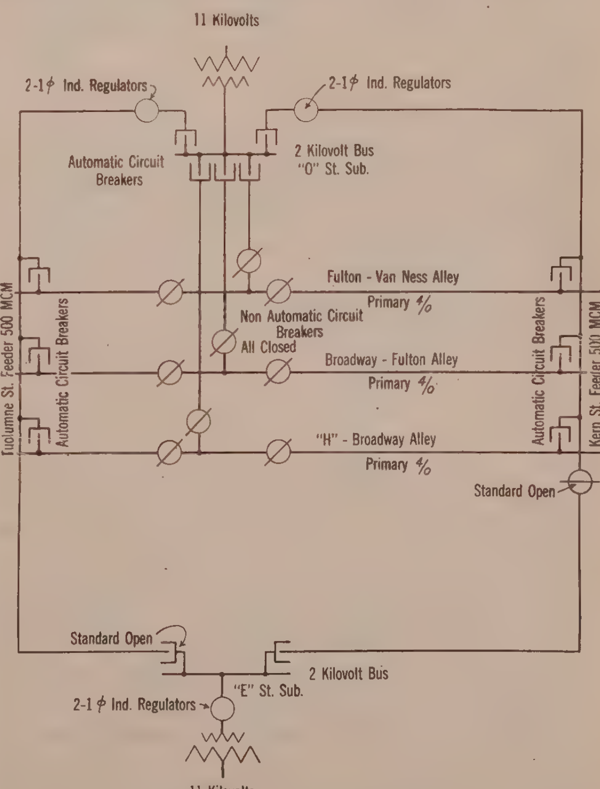

FIG. 16—ONE-LINE DIAGRAM OF PART OF 2-KV. DISTRIBUTION SHOWING REGULATORS

difficulty has been experienced in operating this way. A one-line diagram of this arrangement is included herewith, as are simultaneous voltage charts from the substation bus and the load center.

Transformer Installations

The methods of installing distribution transformer banks used on the San Joaquin System are not widely different from those on other systems, with the exception possibly of the use of fuses manufactured by the company. A few illustrations of typical installations are included in this article.

Fig. 17—A Well, Reservoir and Transformer Installation

The use of light colored paints on distribution transformers has been promoted by this company on account of the high temperatures reached during the summer months in the territory served. It has been found that the use of a light grey paint reduces the oil temperature about four deg. fahr. below temperatures reached by transformers painted with the customary black paint. Exhaustive tests were made on this subject and the data reported to the National Electric Light Association and the various manufacturing companies.

Conclusion

The above paragraphs cover features which are more or less distinctive of the distribution system of the San Joaquin Light & Power Corporation. Some of the problems met and solved are somewhat different from those on other distribution systems, and it is hoped by the authors that the discussion offered may be of interest.

A New Departure in Engineering Education

BY HAROLD PENDER[1]
Fellow, A. I. E. E.

Synopsis.—*A new type of engineering course embodying the basic features of the six-year combined college and engineering course, but possible of completion by a high-school graduate in the usual four year period is described. Briefly, the plan for admission to the engineering school requires at least two years of college training with only part of the subjects prescribed. This is followed by two years in the engineering school, concentrated on the fundamentals of whatever particular branch of engineering (civil, mechanical, electrical or chemical) the student may choose.*

Beginning this fall, the University of Pennsylvania will change over all its engineering courses to this basis. Those responsible for this new type of course believe that it will accomplish the following objects:

1. It will give the student the opportunity of forming a more mature judgment as to whether or not he has an aptitude for engineering, and if not, permit him to continue his studies along other lines without serious handicap.

2. It will impress upon both the student and his parents the fact that engineering is a profession and not a trade; that there is more to an engineering education than merely fitting a boy to get a job.

3. The graduate from this type of course will be as well prepared for his immediate undertaking as the usual technical school graduate, and, in addition, will have the background and broader point of view necessary for real development in his profession.

4. This background and broader point of view will aid him in developing a proper perspective of life as a whole, which, after all, is more important than one's profession.

In one of our leading engineering schools there is, each year, a large influx to the Junior class of students who already hold a college degree but who have decided to specialize in engineering. After a short period required for adjustment, these students almost invariably take an outstanding position in the class, and, what is more significant, in their subsequent careers, rise much more rapidly in their profession to positions of importance than do their less fortunate classmates with only the regular four-year engineering course back of them.

Such a combined college and engineering course requires a period of six years, and the young man is usually at least twenty-four years old before he "gets to work." However, in spite of this fact, for those who can afford it, a six years' course is undoubtedly superior to the usual four years' course, superimposed on a high school training. With most of us, however, the cost of keeping John at college is no small strain on the family pocket-book. The question naturally arises as to whether or not it may be possible to plan a course which will include the essential features of the combined college and engineering course, but which can be completed in four years.

One of the reasons for the superiority of the combined college and engineering course is that a young man who deliberately goes to an engineering school after having spent four years in college, has given serious thought as to whether or not he has the aptitude for engineering, and his judgment is based on relatively mature reasoning. He does not, for example, conclude that he is cut out to become a great electrical engineer simply

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Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

because he has built a radio set or has successfully repaired the front-door bell. Nor does he decide that he can become a great bridge-builder because a friend of his uncle's wife holds an important position with the American Bridge Company.

It is also doubtful whether a young man, who, during his college course, has consistently had difficulty with mathematics and physics, will have, upon graduation from college, the temerity to attempt an engineer ing course. On the other hand, when a boy direct from school starts an engineering course, no matter what difficulties he may encounter in the inevitable mathematics and physics of the freshman and sophomore years, it is seldom possible to persuade him to voluntarily change to some other course for which he may have a real aptitude. There is an admirable persistency about most American boys; but persistency without good judgment is often disastrous. Good judgment comes with maturity, and a boy fresh from high-school is usually "just a boy."

In addition to his greater maturity, the college graduate who takes up the study of engineering has acquired at least some knowledge of the humanities. In after life these will be just as valuable to him as an engineer as they are to the lawyer or to the physician. The lack of a proper appreciation of these values of side cards in the game of life is really the most common cause of failure on the part of the engineer to take, in his community, the position for which his intellectual training otherwise so eminently fits him.

With the idea of enabling the high-school graduate and his brother from the preparatory school to make a rational decision as to whether or not engineering is the career for which he is best fitted, and yet not to handicap him should he find that his aptitudes are along other lines, the University of Pennsylvania has developed a new type of four-year course, which will go into effect with the entering freshman class this fall. In accordance with this new plan, each of the engineering courses given in that institution, (either civil, mechanical, electrical or chemical engineering, as well as the course in chemistry) become, in effect, a combined four year course in the college and in the engineering school.[2] The first two years are spent in the college or academic department, and the last two in the engineering school.

Actually, the student is not admitted to the engineering school until he has completed, with credit, the equivalent of two full years of college work. The specific requirement for admission to the engineering school is that the student must have obtained credit in at least thirty units of college subjects, including five units in English, five units in modern language, six units in mathematics through calculus, six units in college physics and three units in chemistry. The remaining five units and such additional subjects as the student may desire to study are left to the choice of the student under the guidance of a competent advisor. History, psychology, zoology, philosophy, economics, government and similar subjects are recommended for such electives.

There will be special provision made in the college of the University of Pennsylvania to give high-school and preparatory school graduates the necessary pre-engineering training to enable them to fulfill the above requirements, but students who have taken the equivalent preparatory training elsewhere will also be admitted.

During the two years in the College, there will be no distinction made between these pre-engineering students and the regular college students, except to the extent that the pre-engineering students will take a curriculum which is in a large part prescribed. However, should a pre-engineering student at the end of his second year decide that he prefers to remain in the College and be graduated from there, the subjects he has taken will all be accepted for the college degree, and he will be in a position to complete his college course in the usual four years.

The pre-engineering student will not be required, or even encouraged, to make any choice as to which branch of engineering he may wish to take up, until he has completed his sophomore year. During his two years in the College he will, in various outside activities, come in contact with the upper classmen in the several engineering departments and with members of the instructing staff of the engineering school. There will also be opportunities for him to meet and talk with practising engineers in the city and elsewhere. When he does make his choice, he will be in position to make a much more rational decision than would have been possible at the beginning of his freshman year.

Upon his deciding to transfer to the engineering school, the student will be required to give satisfactory evidence that he is capable of both making and reading mechanical drawings. If he has not acquired this ability before the completion of his second year in the College, he will be required to attend a brief summer session just prior to the opening of the fall term, in which summer course the requisite instruction in mechanical drawing and descriptive geometry will be given. A course in mechanical drawing and descriptive geometry will also be given during the regular school year, and such pre-engineering students as may wish to do so, will be permitted to take this course as an extra while they are registered in the College.

The question will naturally be asked how will it be possible, even though the student has all the preliminaries in the way of mathematics, physics, chemistry, language and drawing, to give him in a period of two years sufficient instruction to warrant the award of the bachelor degree? The answer is that a period of two years is ample time for the training of such a student in the

2. At the University of Pennsylvania there are two engineering schools, The Towne Scientific School, in which are given the courses in Civil, Mechanical and Chemical Engineering, and the course in Chemistry, and The Moore School of Electrical Engineering in which is given the course in Electrical Engineering.

fundamentals of a given branch of engineering, providing all specialties and "frills" are omitted. For example, a course of two or three hours per week in Electric Traction makes an excellent appearance in a catalogue, but is such a course really essential, even to a student who, upon graduation, obtains a position with an electric traction company? If the student has acquired a thorough knowledge of the fundamentals of mechanics and electric machinery, he will lose but little time in familiarizing himself with their application to this special case.

That such special application courses as electric traction, illumination, industrial application of motors, telephony, electric machine design, and the like, are not really essential to an undergraduate curriculum, is evidenced by the fact that in many institutions these courses are offered as electives, the student being required to take one or more but not all of them. If they are not all essential, why should any one of them be?

The Pennsylvania plan may best be understood by considering the proposed two years' curriculum for a particular course; for example, electrical engineering. This course, to which no student is admitted until he has completed, with credit, at least two years' of college work, and a course in mechanical drawing, includes the following:

Mechanics of Materials	60 hours
Thermodynamics	30 "
Elements of Structural Design	45 "
Mechanical Laboratory	90 "
Steam Engineering (Steam-electric Power Plants)	60 "
Water-Power Engineering (Hydroelectric Power Plants)	45 "
Direct-Current Circuits and Apparatus, including Electrical Measurements	150 "
Alternating-Current Circuits and Power Apparatus, including Transmission	180 "
High-Frequency Alternating-Current Circuits and Apparatus	75 "
Electrical Laboratory	300 "
Electrical Engineering Seminar	60 "
Differential Equations	45 "
Economics	30 "
Business Law	30 "
General Study Option	180 "
Collateral Reading	180 "
Total	1560 hours

(As there are approximately thirty weeks in the school year, a total of 1560 hours in two years means that the student will carry a roster of twenty-six hours per week.)

An inspection of this curriculum will show that not only is there ample time in the two years to cover the fundamental subjects which an electrical engineering graduate should know, but it will also be possible for the student, in his Junior and Senior years, to continue as a general study option, one or more of the humanistic studies begun in the College. This general study option, for which are provided three hours per week throughout the two years in the engineering school, is for the purpose of broadening the student's intellectual background. Considerable latitude will be given the student in the choice of this option; it may be literature, history, language or science in the College or any subject taught in the Wharton School of Commerce and Finance, for which the student has the necessary preparation.

Under the heading of Collateral Reading, the student will be required to read certain assigned books dealing with engineering practise. These books will be of such a character as to give the student knowledge of the application to specific engineering projects of the fundamental principles which he is studying in class. For example, a book dealing with the practical construction of overhead and underground transmission lines will be assigned for outside reading when the student is studying the principles of transmission and distribution. At the end of each term, a comprehensive examination, covering the collateral reading for that term, will be given.

It is also planned by those in charge to make the necessary arrangements whereby all engineering students at the University of Pennsylvania will have the opportunity of spending at least one summer vacation in actual engineering work in the industries in Philadelphia, or vicinity. For students in electrical engineering, in particular, this summer practise will take the place of the shop-work formerly given to such students in the shops of the engineering school.

For those students, who, upon the completion of the two undergraduate years in the engineering school, may wish to pursue further the study of any particular phase of engineering, or who may wish to equip themselves more thoroughly for engineering research or teaching, graduate courses in the several engineering departments will be offered. Upon the satisfactory completion of a third year in the engineering school, (a year of graduate work following the winning of the bachelor degree), the student will be given the degree of Master of Engineering in Civil, Mechanical, Electrical or Chemical Engineering, as the case may be.

Those responsible for the plan just described believe that it will accomplish these several objects:

It will go a long way toward eliminating, without handicap to the individual, those lacking aptitude for engineering and who inadvisedly attempt to prepare themselves for the engineering profession.

It will impress upon the boy and also upon his parents that engineering is a profession and not a trade; that there is more to an engineering education than merely fitting a boy to get a job.

The graduate from the type of course here described, will not only be as well prepared for his immediate undertaking as the usual technical school graduate, but he will have the background and a broader point of view necessary for real development in his profession.

This background and broader point of view should also give him the proper perspective of life as a whole, and should develop in him interests outside of his own profession, without which no man can rise to a position of real leadership among his fellows.

220-Kv. Transmission Transients and Flashovers

BY R. J. C. WOOD[1]

Associate, A. I. E. E.

Synopsis.—The conclusion has been reached that birds are the cause of flashovers on the Southern California Edison line. The frequency and location of flashovers is given for nine years of operation at 150 kv. and two years at 220 kv. The increase in the number of flashovers when first going to 220 kv. has been reduced so that now there is no greater number than there was at 150 kv. This has been done by installing bird guards which are, however, not yet completely bird proof. Other possible causes of flashovers are considered, including corona, standing and traveling waves of high voltage, harmonic resonance, sustained high-frequency effects, lightning, and highly ionized air. Investigations to discover the presence of such disturbances are described; they included the use of a homemade photographic surge recorder, the klydonograph, and oscillograph. The amplitude of voltage surges caused by various switching operations and the quantity of tertiary and residual current at the different stations on the system are tabulated.

The conclusions reached are that there are not any voltage disturbances of greater magnitude than those produced by normal switching, and that such voltage rises as do occur are totally inadequate to cause flashovers or cause any damage to connected apparatus. The evidence is all against the existence of sustained high-frequency currents or voltages and it may be stated confidently that they do not exist.

* * * * *

FLASHOVERS

The more or less occasional flashovers on the Big Creek Transmission System of the Southern California Edison Company have been the subject of study for several years in the effort to find their true cause, but none of those who studied this problem could find an electrical theory that would explain all the facts. Finally, a man unacquainted with mysterious resonance phenomena and dire high-frequency potentialities observed the one fact that had escaped the rest of us, and, as H. Michener describes in his paper[2] the bird theory was evolved. This theory, that flashovers on this system are due to the excrement of birds falling through the air and affording a conducting path between conductor and tower, is now firmly established and believed by those on the ground.

The frequency of these flashovers from January 1, 1914 to July 31, 1925 is shown in Fig. 1, the voltage of the line being 150 kv. prior to May 6, 1923 and 220 kv. thereafter. The immediate increase of flashovers is noticeable when the raise in voltage increased the size of the bullseye which the bird had to hit in order to score. It will also be seen that since the installation of various kinds of bird guards, which was done mainly during the last half of 1923, that the occurrence of flashovers has been of about the same frequency as during 150 kv. operation.

When it was first determined to put on bird guards, two factors were underestimated; first, the lateral distance from the center line of the insulator string from which a roosting bird could cause a flashover when the wind was in the right direction to carry the stream of excrement into the vicinity of the conductor, and secondly, the birds intelligence. He had used that tower for a roost and observation point for years and looked upon any effort to oust him as an invasion of his rights, and he proved quite clever in surmounting the difficulties first put in his way.

In the winter months of 1924-25 observation on the line showed that the birds, prevented from roosting on the more accessible parts of the tower, were accommodating themselves to new conditions and getting in on secondary members of the steel work that it had at first been considered unnecessary to guard, so that the line is not yet fully equipped with absolutely bird proof devices and the flashovers still occurring have in each case been traced to imperfect bird guards.

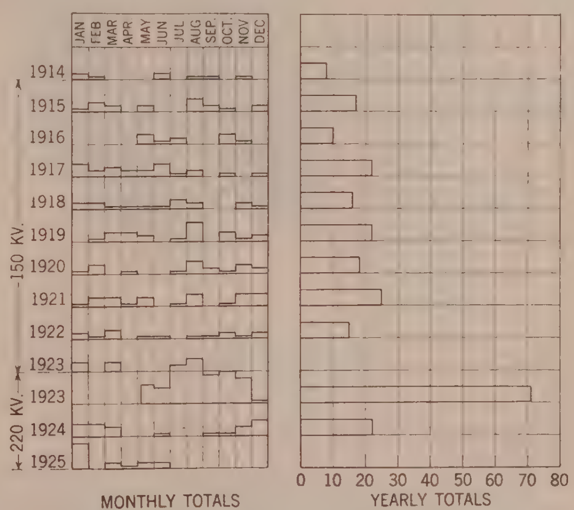

FIG. 1—RECORD OF THE NUMBER OF FLASHOVERS ON BIG CREEK LINES; TOTALS BY MONTHS AND YEARS

The commercial significance to service of the flashovers has become a vanishing quantity now that reliable automatic relays are in use, provided duplicate sectionalized lines are available which will not be overloaded upon the loss of a section. The effect of a flashover upon received voltage and frequency is shown in Fig. 2 and is seen to be inconsiderable and momentary.

The space distribution of flashovers along the line is given in Fig. 3, the remarkable similarity between the distributions for 150-kv. and 220 kv. operation is at once apparent. This in itself is significant of no new

1. Research Engineer, Southern California Edison Co.
2. Transmission at 220 kv., Section 1, by H. Michener.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash. September 15-19, 1925.

factor having arisen with the increase of voltage, in fact, it is very evident that the tendency to flashover chiefly depends upon the location of the insulator along the line.

Possible Causes of Flashovers

Considering other possibilities than birds, the exciting cause of flashovers might be either internal, such as standing or traveling waves of abnormal voltage, or sustained high-frequency capable of breaking down relatively large air spaces; or external, such as lightning or highly ionized air.

The three horizontal conductors are asymmetrical with regard to the ground wire so that the outer conductor most remote from it should suffer most from lightning disturbance. During 150-kv. operation, 66.3 per cent of flashovers were on the middle conductor,

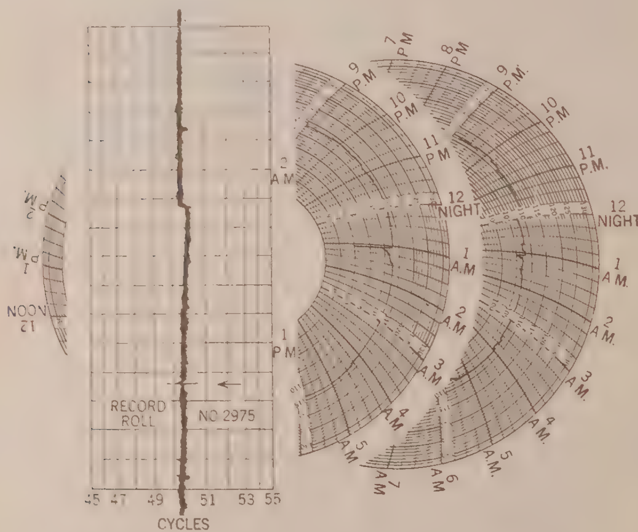

Fig. 2—Disturbance Caused by Flashover to System Frequency and Voltage at Two Kv. Substations

after going to 220 kv. this percentage increased to 88.5 per cent.

Evidently, no distributed atmospheric affect is responsible. This eliminates ionized air and lightning, especially since practically all of the flashovers have occurred when there was no lightning.

The possibility or otherwise of internal disturbance is not so easily disposed of, and in an effort to clear up this question a few investigations were undertaken.

Corona

It has been suggested that corona on the arcing horns of the old 150-kv. equipment might be a starting point for the high-frequency streamer, in fact, that the least bit of corona was a dangerous thing to have around. In November 1921, hollow copper balls, some 3-in. and some 4-in. diameter, were put over the ends of the arcing horns on the middle conductor of the East Line from mile 105 to mile 163 where, as may be seen in Fig. 3, flashovers were above the average in frequency. These balls suppressed the corona, did not decrease the arcing distance and improved the voltage distribution of the insulator string, but the three next flashovers in that month and three out of four in December were over ball protected insulators. Evidently, corona was not the cause of the breakdowns.

Photographic Surge Recorder

At the time these matters were being studied in 1921,

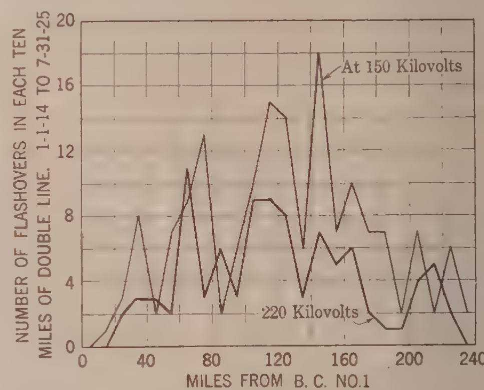

Fig. 3—Space Distribution of Flashovers Along Line

preparatory to increasing the line voltage to 220 kv., there did not appear to be available any commercial voltage surge recorders that were suitable to our purpose, so we combined a kodak film with the clockwork mechanism of a curve drawing wattmeter, and there resulted a somewhat crude daylight loading surge recorder using standard 3A film.

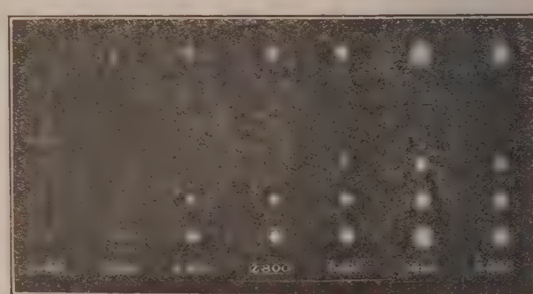

Fig. 4—Calibration of Surge Recorder on A.-C. Voltage

Six hemispherically-ended metal wires, together with a grounded metal drum, formed six spark-gaps of different lengths through which the film passed. The spark-gap terminals were all connected in parallel across the ground-end unit of a string of insulators hung from the line under test, and so shielded as to provide a suitable voltage for the recorder. The parallel gaps broke down successively at increasing voltages as long as the insulating celluloid film was in them, as shown in Fig. 4, which is a laboratory calibration using a-c. voltage. The film was driven by a weight-actuated mechanism, the

clock regulating the speed. The whole device was enclosed in a wooden box supposed to exclude light. One of the spark-gaps was used to mark time, being in series with a commutator that broke circuit every two hours and was driven by the same clock that regulated the film speed. The instrument is shown in Fig. 5.

This instrument was in use on the Eagle Rock 150-kv. bus for three months and was then installed at Vestal. A record obtained by its use is shown in Fig. 6. The broad band at the left is the discharge from the

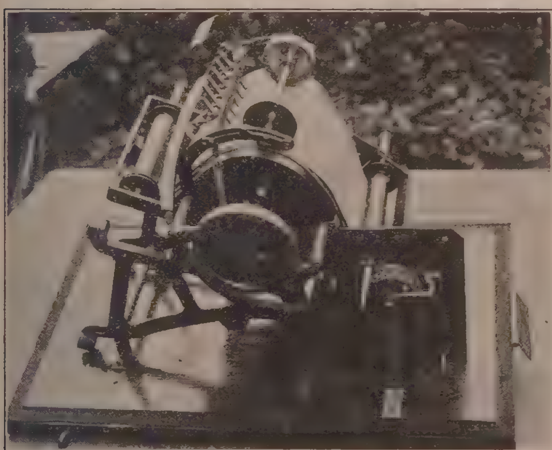

Fig. 5—Photographic Surge Recorder

first gap which was set at just below normal voltage, the second gap went over at approximately 1.25 and the third one at 1.50 times normal voltage. The right hand band is from the timing point working indifferently well.

It was the general rule to kill the bus before admitting

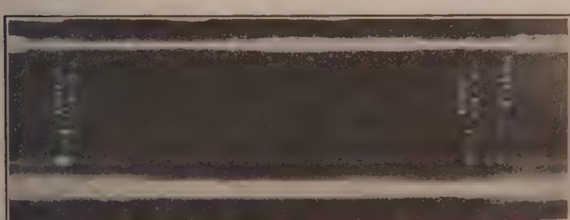

Fig. 6—Surges Recorded at Eagle Rock on 150-Kv. Bus

any one to the bus compartment for the purpose of changing films, and it was soon found that this station switching caused the highest voltages that were recorded, none of which, however, exceeded approximately double normal. The recorder was in operation upon the 150-kv. bus at Vestal after the line had been raised to 220 kv. but was never installed directly upon the 220 kv. line. It had satisfied us that there were no voltage surges on the 150-kv. system of anywhere near sufficient magnitude to cause flashovers.

This recorder suffered from many defects, largely of a mechanical nature; difficulty was encountered in getting the film to reel up smoothly on the receiving spool, and considerable fogging of the film took place when installed out of doors from leakage of light through the containing wooden box, the time-recording device was imperfect, and the indications were not at all

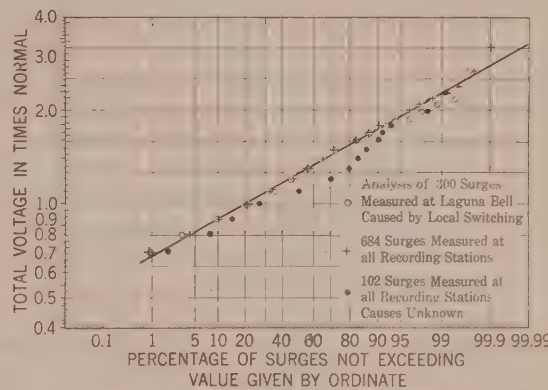

Fig. 7—Relative Percentage of Voltage Surges of Different Amplitudes

precise increasing as they did by 25 per cent steps. Still it worked after a fashion and indicated conditions that have since been confirmed by more perfect apparatus.

Klydonograph Tests

Some time later, the Westinghouse Electric Company brought out its Klydonograph[3] surge recorder in which

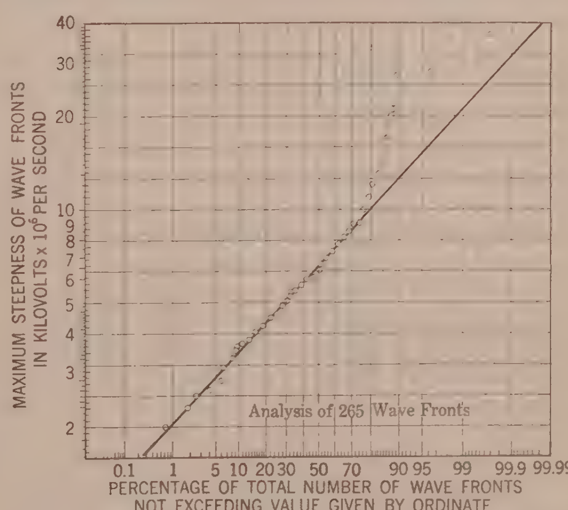

Fig. 8—Relative Percentage of Wave Fronts of Different Maximum Steepnesses

only one recording point is used and the magnitude and character of the voltage estimated from the size and nature of the picture produced. Through the courtesy of the Westinghouse Co., installations were made at Big Creek No. 1, Vestal, Magunden and Laguna Bell.

3. The Klydonograph and its Application to Surge Investigation, by J. H. Cox and J. W. Legg.

These installations were in service 89 days at Big Creek No. 1, 75 days at Vestal, 71 days at Magunden and 119 days at Laguna Bell. There were 684 indications of voltage rise and 556 indications of wave front slope recorded. More than a normal amount of switching was being done at the time as one line was taken out of service every night to reduce losses. The approximate number of oil-switch operations performed on the 220-kv. system averaged over 36.3 per day and about 18 daily oil-switch operations were made on the 150-kv. station busses which are conductively coupled to the 220 lines through auto-transformers. The average total number of surges per day was 8.71. The ratio of number of surges to switchings being 24 per cent if only the 220-kv. switching is considered and only 16 per cent if the 150-kv. switching be included.

The relative percentage of abnormal voltages of different magnitudes is shown in Fig. 7 plotted upon probability paper. The very close conformity of the plotted results with a straight line indicates both that a sufficient number of observations were obtained to get representative results, and also that no particular predominating cause exists that is responsible for surges of any particular value.

The curve for surges measured at Laguna Bell, due only to local switching operations, is practically coincident with the curve of all causes for the whole of the system. From this we may conclude that the magnitude of the voltages resulting from normal switching operations was, on an average, independent of the location of the switching.

The surges of unknown origin which could not be correlated with switching on the 220-kv. system average of lesser magnitude.

The steepness of wave fronts is shown in Fig. 8. In this case the probability law is followed up to wave fronts of about 10×10^6 kv. per sec. Above this value results are erratic. This is explainable by the fact that the greater part of the observations between 2×10^6 and 10×10^6 kv. per sec. were obtained at Laguna Bell as the result of a great number each, of a number of different switching operations, whereas the steeper slopes were observed at Vestal and Magunden and are inherent to a few particular operations at those stations. The curves therefore seem to indicate that slopes of wave fronts originating at different stations are of different orders of magnitude, whereas, the amplitudes of potential surges at different stations are of the same order. It may be pointed out for comparison that the maximum steepness of normal 50-cycle sinusoidal waves at 220 kv. is 0.0564×10^6 kv. per sec.

The evidence as to the extent that surges are transmitted over any considerable distance is rather hard to interpret depending somewhat upon the definition of the word "surge."

A surge might be considered to have traveled:

1. When a voltage rise is due to switching at a distance.
2. When antenna indications of current waves show them to have traversed certain distances.
3. When records of voltage rise are found at two or more separated points all due to a common localized cause.

TABLE I
TRANSMISSION OF VOLTAGE DISTURBANCES

Recording Station	Number of disturbances Recorded at Laguna Bell	Magunden	Vestal	B. C. No. 1
Total Number recorded	402	38	17	41
Number originating at Laguna Bell and also recorded as shown	..	0	0	0
Ditto originating at Magunden	3 2	.. ..	0 0	0 2
Ditto originating at Vestal	1	0	..	0
Ditto originating at B. C. No. 1	0	0	0	..
Ditto origin unknown	1	0	0	1

It has been thought best to confine the evidence to that under heading No 3, as this required direct proof of the transmission of a voltage disturbance, while Nos. 1 and 2 do not necessarily do so. Such evidence is given in Table I and shows to what an insignificant amount such action occurs over the distances in question.

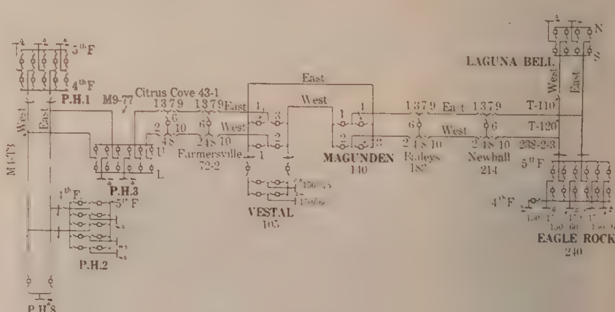

Fig. 9—Switching Diagram of 220-Kv. System

The antenna instruments gave many indications of current rushes in the line without corresponding voltage records being obtained. Apparently there was not any definite relation between voltage amplitude and wave front steepness.

For those who care to analyze further, Fig. 9 presents a switching diagram of the system and Tables II and III show the different switching operations performed, together with the range of the resulting surges.

It should be noted that even though the disconnects at the main switching stations only make or break the charging current of a few feet of bus and one side of an open oil switch, that when so doing they cause voltage rises of as high a value as do other switching operations that involve 100 miles of line.

TABLE II

CAUSES AND MAGNITUDES OF SWITCHING SURGES

A. SURGES MEASURED AT LAGUNA BELL

Location of Switching	Nature of Switching	No. of Records Obtained	Total Voltage in Times Normal		
			Min.	Avg.	Max.
B. C. No. 1	Disc. closed	1		1.2	
	West Line closed	1		1.1	
B. C. No. 8	East Line closed	3	0.9	1.1	1.4
	West Line closed	1		1.5	
B. C. No. 3	East Line opened North	1		1.1	
	East " " South	5	1.1	1.3	1.6
	" " closed South	1		1.2	
	West " opened South	5	1.5	1.6	1.6
	" " closed South	1		1.3	
	Disc. closed	1		1.6	
Citrus Cove	Parallel opened	3	1.0	1.2	1.3
	" closed	1		1.7	
Farmersville	" opened	6	1.1	1.2	1.5
Vestal	East Line opened North	6	0.9	1.5	1.8
	" " " South	3	1.0	1.2	1.4
	West " " North	3	1.1	1.2	1.3
	" " " South	6	1.1	1.3	1.5
	" " closed North	1		1.3	
	" " opened South	4	1.0	1.4	1.7
	Disc. opened	2	1.4	1.7	2.1
Magunden	East Line opened North	4	1.1	1.6	2.3
	" " " South	3	1.3	1.5	1.8
	" " closed North	6	1.1	0.3	1.4
	West " opened South	27	0.8	1.3	2.4
	" " closed North	4	0.9	1.0	1.1
	" " " South	6	1.0	1.3	1.8
	Disc. opened	3	1.4	1.7	2.2
	" closed	1		1.1	
Newhall	Parallel opened	3	1.1	1.2	1.4
	" closed	1		1.0	
Laguna Bell	East Line Opened	32	0.7	1.3	1.9
	" " closed	10	0.8	1.0	1.5
	West " opened	34	0.8	1.3	1.9
	" " closed	26	0.8	1.3	2.2
	Changed from South to North bus	72	0.8	1.4	2.1
	" " North to South "	61	0.7	1.4	2.2
	Parallel busses	10	1.0	1.3	1.7
	North bus opened	2	1.0	1.1	1.1
	South " "	4	1.2	1.5	1.8
	" " closed	3	1.6	1.7	1.8
	Disc. opened	14	1.1	1.5	1.9
	" closed	1		1.6	
	Transformer put on bus	1		1.1	
	" taken off "	8	0.9	1.4	1.8
	Changed Transformers	7	0.9	1.2	1.8

B. SURGES MEASURED AT MAGUNDEN

Location of Switching	Nature of Switching	No. of Records Obtained	Min.	Avg.	Max.
B. C. No. 3	East Line opened South	2	0.9	0.9	0.9
	" " closed "	1		1.5	
Vestal	West " " "	1		1.5	
Magunden	East " opened South	2	1.3	1.3	1.3
	" " closed North	1		1.2	
	" " " South	7	1.2	1.7	2.2
	West " opened South	10	0.8	1.1	1.5
	" " closed North	2	0.7	1.1	1.6
	" " " South	9	0.8	1.3	2.1
Newhall-Baileys	Disc. opened	3	1.2	1.6	2.0

C. SURGES MEASURED AT VESTAL

Location of Switching	Nature of Switching	No. of Records Obtained	Min.	Avg.	Max.
Farmersville	Disc. closed	1		2.0	
Vestal	East Line opened South	2	1.0	1.0	1.0
	" " closed North	1		2.0	
	West " opened South	3	0.9	1.7	2.1
	" " closed South	5	1.3	2.0	2.4
	Disc. opened	1		1.2	

TABLE II (Continued)
CAUSES AND MAGNITUDES OF SWITCHING SURGES

Location of Switching	Nature of Switching	No. of Records Obtained	Total Voltage in Times Normal		
			Min.	Avg.	Max.
	D. SURGES MEASURED AT B. C. NO. 1				
B. C. No. 1	East Line closed	2	1.7	1.7	1.7
	West " opened	1		2.0	
	" " closed	4	0.9	1.5	2.2
	Disc. closed	1		1.3	
	Generator taken off	2	1.7	1.8	1.8
B. C. No. 2	East and West lines parallel	1		1.9	
B. C. No. 8	" " " " "	1		1.9	
B. C. No. 3	East Line closed North and South	1		1.9	
	West " " South	3	2.0	2.1	2.3
Farmersville	Parallel opened	1		2.0	
Vestal	East Line opened North	10	0.8	1.5	2.3
	" " " South	1		2.3	
	West " " North	1		2.0	
Tower 118-5	Flashover, East Line	1		1.9	
Magunden	East Line opened South	2	1.6	2.0	2.3
	" " closed North	3	1.2	2.1	3.2
	" " " South	1		1.7	
	West " opened South	2	1.7	1.7	1.7
	Disc. opened	1		1.7	
Laguna Bell	East Line opened	1		1.9	

Some explanation of the meaning of voltage rises of less than 1.0 times normal is due.

The klydonograph actually records a measured fraction of the line voltage, an electrostatic potentiometer being used to effect this. Between the klydonograph and potentiometer is a sphere-gap adjusted to breakdown for a slight increase in line voltage and give a corresponding size of picture on the photographic plate.

TABLE III
MAGNITUDE OF SURGES
SURGES OF UNKNOWN ORIGIN

Measured at	No. of Records Obtained	Total Voltage in Times Normal		
		Min.	Avg.	Max.
Laguna Bell	86	0.7	1.2	2.3
Magunden	4	1.1	1.2	1.5
Vestal	3	1.1	1.1	1.2
B. C. No. 1	9	0.9	1.5	2.0

Records were occasionally found upon the plate corresponding in size to voltages less than the normal breakdown value of the sphere-gap, and these have been included in the tabulations, as found, as less than unity surges. The calibration of the photographic plate at these low voltages is somewhat uncertain especially when the duration of the surge is so short that only a few rays are formed in the picture and this is the probable explanation of pictures of a size less than corresponds to the series spark-gap. In any event these apparently subnormal surges are only of academic interest and have no bearing upon flashovers. At supernormal voltages the accuracy of the calibration is probably well within 15 per cent at twice normal voltage and better yet at higher voltages. Calibrations made at the factory, in the Southern California Edison laboratories and in the field, check very well and prove that the obtaining of 0.7 times normal pictures does not mean that the whole calibration of the klydonograph is 43 per cent low.

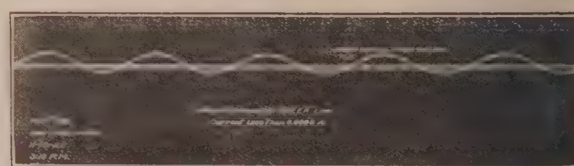

Fig. 10—Line Voltage to Ground at Big Creek No. 3

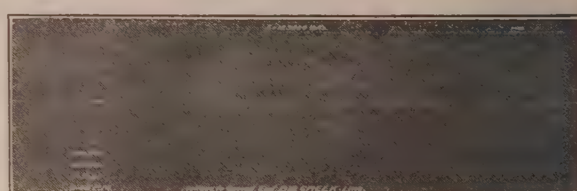

Fig. 11—Line Voltage to Ground at Vestal

Tertiary and Residual Currents

To determine whether there were any abnormal residual, tertiary, or other odd harmonic currents or voltages a number of oscillograms were taken, nothing

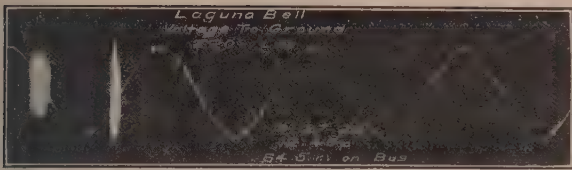

FIG. 12—LINE VOLTAGE TO GROUND AT LAGUNA BELL

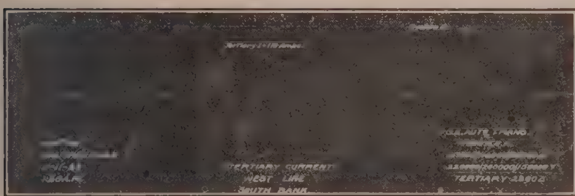

FIG. 13—TERTIARY CURRENT IN AUTO-TRANSFORMERS AND SECONDARY VOLTAGE AT BIG CREEK NO. 2

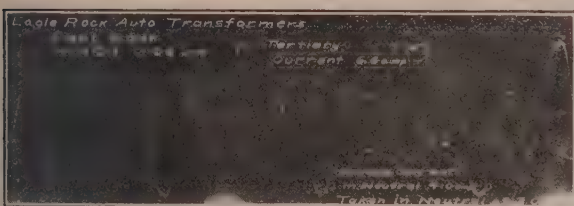

FIG. 14—TERTIARY AND RESIDUAL TO GROUND AT EAGLE ROCK

FIG. 15—RESIDUAL TO GROUND AND SECONDARY VOLTAGE, AT BIG CREEK NO. 1

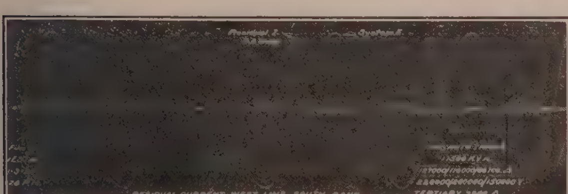

FIG. 16—RESIDUAL TO GROUND AND SECONDARY VOLTAGE AT VESTAL

FIG. 17—RESIDUAL TO GROUND AT LAGUNA BELL

out of the ordinary being done, except, perhaps, in obtaining oscillograms of line voltage direct without interposing potential transformers.

This was accomplished by using a 50-ft. length of ½-in. common garden hose filled with water as a resistance in series with the oscillograph element, with a precautionary shunt, in parallel with the element. No special difficulties were encountered except that in the

TABLE IV
TERTIARY CURRENTS IN AUTO-TRANSFORMERS

Station	Transf. Bank	Tertiary Amps.	Rated Voltage of Tertiary	Approx. Per cent of rated Voltage on Transf.
Eagle Rock.....	East Line	6.6	11.000	86.4
	West Line	7.5	11.000	86.4
Vestal..........	North	128.	2900	96.9
	South	149.	2900	96.9
B. C. No. 1.....	North	119.	2900	100
	South	116.	2900	100
B. C. No. 2.....	East Line	122.	2900	100
	West Line	116.	2900	100

first trials the water in the hose lowered in level at the high voltage and, due to leakage and evaporation, whereupon a small internal arc burned up that end of

TABLE V.
RESIDUAL CURRENTS TO GROUND

Station	Transf. Bank	Residual Amps.	Rated Voltage
Eagle Rock......	East	4.0	220000/150000
	West	4.0	“ “
Laguna Bell.....	No. 1	2.8	200000/72000
	No. 3	1.6	“ “
Vestal..........	South	0.6	220000/150000
	North	0.6	“ “
B. C. No. 1......	North	0.84	220000/150000
	South	0.88	“ “
	No. 1 Zero	0.96	6600/150000
	No. 2 load	0.96	“ “
	No. 3 16000	0.20	“ “
	No. 3 Kw.	0.84	“ “
B. C. No. 2......	No. 1	1.52	6600/150000
	No. 2	1.52	“ “
	No. 3	1.52	“ “
	Total No. 1, No. 2, No. 3	3.52	“ “
	E Line	1.24	220000/150000
	W Line	1.44	“ “
	No. 3 4000 Kw.	1.6	6600/150000
	No. 3 7000 “	1.6	
	No. 3 9500 “	1.6	
B. C. No. 8......	Total less than	.04	11000/222000
B. C. No. 3......	No. 1	2.72	11000/220000
	No. 2	2.88	“ “

the hose. This difficulty was entirely overcome by having a small reservoir of water (old 5 gal. oil can) at the high-voltage and high-level end, this supplied losses

and kept the hose full of water. The current through the hose and oscillograph to ground varied from 37.0 milliamperes at Laguna Bell, to less than 0.3 milliamperes at Big Creek No. 3, showing resistances of the 50 ft. of hose of 3.36 and 423 megohms respectively. This, it may be remarked parenthetically, is truly indicative of the relative difficulties in the two locations of obtaining good ground connections for transformer neutrals.

Efforts were also made to determine the crest voltage on the line by direct sphere-gap measurements putting the sphere-gap at the ground end of the 50-ft. hose full of water. The drop of voltage along the hose due to charging currents rendered the method useless and we had to be satisfied with the wave shape of voltage obtained as previously described.

The results of the investigations were negative so far as supplying any reason for flashovers was concerned. Third, fifth, and ninth harmonic currents were no larger than was to be expected and voltage waves were apparently so nearly sinusoidal that we did not indulge in harmonic analysis.

Examples of the results are shown in Figs. 10 to 17 which are self-explanatory. Table IV gives a summary of the magnitude of tertiary currents and in Table V will be found the values of residuals to ground. These residuals are due to the impedance of tertiary windings, generator harmonics other than multiples of the third, and unbalance of the lines which are not transposed, and possibility to slight transformer inequalities. Considering the magnitude of the system, and the untransposed line, the residuals are small.

The search for abnormal and startling effects has been distressingly unsatisfactory from a spectacular point of view, but most reassuring to those who contemplate the use of high voltages for transmission. Not only have no unusual effects been discovered but not even the beginning or tendency towards them has been made manifest. We have particularly looked for evidence of sustained high frequencies; we are confident there are none.

Conclusions

1. Corona in the amount found upon arcing horns did not cause flashovers.
2. No voltage surges occur of sufficient magnitude to cause flashover or damage to apparatus.
3. Switching causes rises of voltage as great as any recorded.
4. Voltage rises recorded at the times of two flashovers may have been due to subsequent switching and were less than many known to arise from switching.
5. High-voltage switching as practised on this system may be done without fear of danger.
6. Only very occasionally did voltage surges travel even 35 miles without being greatly attenuated.
7. Such alternating surges as were found were highly damped, being usually of but one alternation.
8. There were no harmonic resonances or distortion of voltage wave shapes.
9. Residuals to ground were small.
10. There were no sustained high-frequency effects.

Acknowledgments

The author is pleased to acknowledge his indebtedness to Mr. W. W. Lewis of the General Electric Company for his kindly assistance and direction in the field in taking and interpreting wave shapes and to Messrs. J. H. Cox and L. Gale Huggins for indefatigable work with the klydonographs and again to them and the Westinghouse Company for permission to borrow freely from their report, which has furnished the substance for a great portion of this paper. Mention must also be made of the unselfish consideration of Messrs. J. H. Cox and J. W. Legg, who withheld a great deal from their own paper[3] so that this presentation of the search after the abnormal might be more comprehensive and complete in itself.

3. loc. cit.

Advances in Use of Electricity in Mines

By Committee on Applications to Mining Work[1]

THE work of this committee is, of necessity, limited very largely to the securing of papers from representative mining engineers.

During the year several such papers have been presented, including one by W. C. Adams of the Allen & Garcia Co., on "Coal Mine Electrification;" one by Shelton and Stoetzel on "Electric Shovels;" one by W. C. Clark of the Westinghouse Co. on "Application of Motors to Mine Locomotives;" and one by your Chairman, entitled "Electricity in Mines."

The subject of mining does not seem to particularly interest many A. I. E. E. members, and it was very difficult to draw out a good discussion on any of these papers. The reason for this, the author believes, is more or less obvious and is due, at least in part, to the fact that the mining profession in general feels that the A. I. E. E. as a body is not particularly interested in its problems. The Chairman is convinced that the

1. Annual Report of Committee on Applications to Mining Work.

F. L. Stone, Chairman,
R. T. Andrea, C. N. Beebe, M. C. Benedict, Graham Bright, H. W. Eales, L. C. Ilsley, G. M. Kennedy, R. L. Kingsland, A. B. Kiser, John A. Malady, D. C. McKeehan, W. F. Schwedes, W. A. Thomas, C. D. Woodward.

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y. June 24, 1925.

only way to stimulate interest at a mining meeting and possibly break down this impression, is by holding the mining session in conjunction with some local mining society. If this is done, it seems certain that the members of the mining society will turn out and will be glad to cooperate and participate in the discussion of such points of interest as may arise.

There seems to be very little constructive work for the committee on mine applications. This field has been very well covered by other organizations; thus it would seem that the only work left for this committee is to keep constant watch on the development and assist, whenever possible, in the improvement of mine electrification.

During the year there has been no outstanding and novel development in the application of electricity to mining projects, but, on the other hand, there has been a steady and healthy growth of this application. Larger projects have been undertaken and put through to a successful finish than ever before. One notable instance is the five-mile belt conveyor underground at the Colonial Mine of the H. C. Frick Coke Co. Here we have coal transmitted on a belt conveyer from the mine face to the docks, a distance of approximately five miles, on twenty sections of conveyer at a speed of 450 to 500 ft. per minute. This conveyer has a potential capacity of some 10,000 tons per day. It has been in operation for some considerable time and can be stamped as entirely successful.

Another notable installation is that of the largest coal mine hoist in the world; namely, the 4000-h. p. Ward-Leonard coal mine hoist which operates in the Orient No. 2 Mine of the Chicago, Wilmington & Franklin Coal Co.

The Old Ben Coal Co. has purchased three 2200-h. p. coal mine hoists, two of which are in operation, the third to be installed shortly.

From a business standpoint, the bituminous mining industry finds itself today in a very unfortunate condition.

The majority of coal operators feel that cheaper production of their product will help matters to a considerable extent. The author believes the actual savings that result from complete electrification are not fully appreciated by all operators. Reliable records show savings as high as 25 cents per ton, resulting from change-over from steam to electricity in the same mine. Further, the stand-by losses when mines are electrified are very greatly reduced, so that shut-downs and idle periods are not such serious matters from a cost standpoint with electrified mines as they are with steam-driven mines.

The electrification of coal loading machinery is receiving a great deal of attention from the manufacturing engineers as well as from the coal mine operators. There is no other practical method of drive for these machines, and, like the majority of mine applications, improper motors have been applied on early machines with the usual result.

There is still a great deal of work to be done of an educational nature so far as the mine operator is concerned. The motors required for his work should be, almost invariably, of a special design, laid out to meet mining conditions. Standard industrial motors are very rarely applicable to this class of work, and their application usually ends in delays and dissatisfaction.

In conclusion, it is suggested that something might be accomplished by the formation of a joint committee on Application of Apparatus to Mines; this committee being made up of the chairmen of the various committees at work on this subject in other societies such as the American Institute of Mining and Metallurgical Engineers, the American Mining Congress and the United States Bureau of Mines; these gentlemen meeting with the chairman of the committee on "Application of Electricity to Mines" of the American Institute of Electrical Engineers; this latter body possibly acting as sponsor for such a committee. Such a committee could review the work already done along this line and suggest changes or give its approval.

The most outstanding work along this line has been done by the committee on Underground Transmission and the committee on Power Equipment of the American Mining Congress. These committees, working jointly, have prepared a set of rules and suggestions for the installation and care of electrical apparatus in and around mines. These rules and suggestions are, at the present time, before the American Engineering Standards Committee for its approval. A committee made up of the personnel above suggested might go over these rules and suggestions in a constructive manner, and, if their approval is received, would undoubtedly help the mining industry to some extent at least.

UNIQUE SWIMMING POOL ILLUMINATION FURNISHED BY UNDERWATER FLOODLIGHTS

A unique electrical installation, consisting of an underwater illumination system, has recently been placed in operation in a large bathing pool in the vicinity of San Diego, California. Embedded in the walls of this pool is a set of large flood lights, placed at a depth of 9 feet. The lighting units are enclosed in a large pyramid-shaped casting, having a vent at the top leading through a goose-neck to a manhole back of the pool walls. The lamp unit is protected from the water by an 18-inch disk of Pyrex glass 7/16 inches thick. Difficulties as to the cracking of heavy plate glass had been numerous until the adoption of the heat-resisting glass. Water on one side of the glass at low temperature and the heat generated by a 500-watt lamp in the unit on the other side of the glass, together with moisture, condensation, and other mechanical factors, have provided considerable basis for experimentation on this installation.

Losses in Iron Under the Action of Superposed
Alternating- and Direct-Current Excitations

O. E. CHARLTON*
Enrolled Student, A. I. E. E.

J. E. JACKSON†
Enrolled Student, A. I. E. E.

***Synopsis:**—The paper presents the results of wattmeter measurements of iron loss in a small experimental reactor designed for a-c. and d-c. excitations. All the resistances were measured by the d-c. voltmeter-ammeter method, and the $I^2 R$ losses were subtracted from the total wattmeter readings. A-c. core losses are plotted against d-c. excitation for various a-c. flux densities. These curves were checked qualitatively by means of hysteresis loops taken with a special bilateral oscillograph.*

All results show a comparatively small change in core loss as d-c. excitation is added, the core loss even showing a decrease when the a-c. saturation is high.

The core loss proper is distinguished from the double frequency circulating current copper loss, and means are given for decreasing this $I^2 R$ loss.

* * * * *

Introduction

In thesis work at Massachusetts Institute of Technology in 1924, the authors investigated the losses in iron under the action of superposed alternating- and direct-current excitations, and the results of this investigation are given herewith. This paper was prepared while the authors were connected with that Institute.

The question of superposed excitation is one of wide interest in electrical engineering as it occurs in one form or another in many electrical machines. Perhaps the best known example is the d-c. saturated regulator and reactor. Some rectifier circuits have transformers that are partially saturated with direct current, and the question of iron loss may be very important in connection with the proposed high-voltage, d-c. transmission. Practically all rotating machinery is subject to magnetization at two or more frequencies at the same time, especially in the teeth and pole tips. Telephone and telegraph circuits also carry both direct and alternating currents in many cases.

Previous investigators in this field have found, in the main, a very decided increase in a-c. iron loss with an increase in d-c. bias, sometimes amounting to fifteen or twenty times the usual core loss. Only a few reports show any decrease in the iron loss. In most of those which show excessive losses, the circulating double frequency current which appears in the d-c. circuit or in some other winding on the core when direct-current excitation is added, has either been neglected or there have been other possible errors in the method of measuring the core losses.

They all agree, however, that the classical formula of Steinmetz expressing hysteresis loss does not hold at high-flux densities. Ball and others have attempted to fit the Steinmetz equation to the case of superposed fluxes by changing the value of the exponent and using some value of B which is a function of both the a-c. and d-c. flux densities. Although the authors cannot, at the present time, propose an exact formula, they believe that the hysteresis loss actually begins to decrease at very high d-c. flux densities, and finally becomes zero when the total change in flux caused by the a-c. component takes place above the saturation point of the iron.

The eddy-current component of core loss depends upon the a-c. flux change and not upon the d-c. component, and if the a-c. flux wave remains sinusoidal, the eddy-current losses should not change with an increase of d-c. excitation. As a matter of fact, the wave forms do become somewhat distorted, and the eddy-current loss probably goes up somewhat when direct current is added.

The authors found that total core losses remain practically constant for a given a-c. flux density, regardless of the amount of d-c. flux in the iron, though some change did occur at high and low a-c. flux densities. The losses increased when d-c. excitation was added if the a-c. saturation was low; and decreased if high. The loss curves were taken from wattmeter readings and were checked by dynamic hysteresis loops taken with a bilateral oscillograph. A study of the accuracy of this oscillograph was also made and they believe the loops shown are substantially correct.

Method of Test

The method consisted of measuring the total input to an iron-core reactor by a low power factor wattmeter and subtracting the $I^2 R$ losses in the windings, leaving the difference as the core loss of the reactor. Two circuits were used. One had the direct current and alternating current in series in the same coil, forcing all of the $I^2 R$ loss into this one coil where it could be easily measured; the other had three coils, two carrying direct current and the third, alternating current alone. The latter had the advantage of better wave form but still brought the second harmonic current into one winding where it could be measured.

The series circuit is shown in Fig. 1. A storage battery supplied the direct current and a series resist-

* Alabama Power Co., Birmingham, Ala.

† General Electric Company, Schenectady, N. Y.

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

ance regulated its value. Dynamometer ammeters were used to measure the current. A transformer kept the direct current out of the alternator windings. All voltage and frequency regulations were made with the field controls of the 5-kw. motor-generator set. The core under investigation weighed 20 lb. It was built up of 25-gage (0.022-in.) U. S. electric sheet with lap-joints. The outside dimensions of the core were 9 by 9 by 2 in. The cross-section of the middle leg was 2 by 2 in. while that of the rest of the core was 1 by 2 in. This gave 4 sq. in. for the a-c. flux path and 2 sq. in. for the d-c. flux when the three-coil circuit was used.

In taking readings, it was found necessary to measure the resistance at every point because of the effect of temperature changes while taking data. This was done

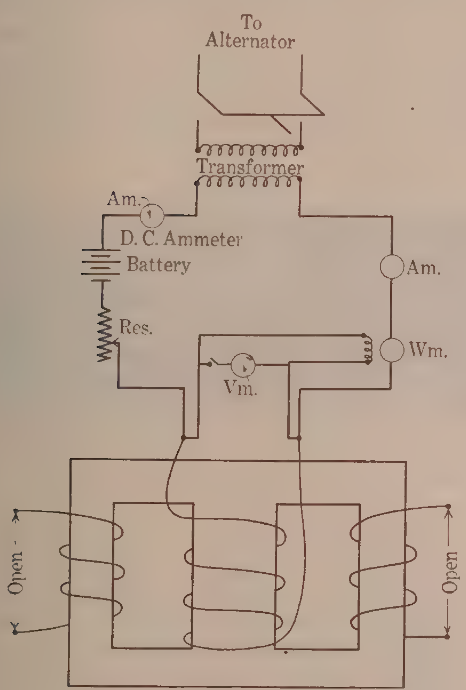

Fig. 1—Series Connection Showing Positions of Instruments

by the voltmeter-ammeter method using double-pole, double-throw switches to put the direct current alone in the windings. Carefully calibrated d-c. instruments were used, as the resistance had to be known with great accuracy in order to make the "subtraction method" at all reliable. With this arrangement, however, no difficulty was found in checking readings at different temperatures.

Fig. 2 shows a set of curves of core loss at various flux densities taken with the series circuit. The densities marked on the curves were figured from the applied voltage, and sine waves were assumed. If corrected for wave form and $I\,R$ drop, the values would be slightly lower than those indicated.

Since these curves did not agree at all with some similar curves taken at Massachusetts Institute of Technology in 1923, or with the results of other investigators, an attempt was made to discover the discrepancies. The circuit used in the M. I. T. report of 1923 is shown in Fig. 3. On considering this circuit, it was found that an alternating current of double frequency must flow in the direct current circuit, even though the

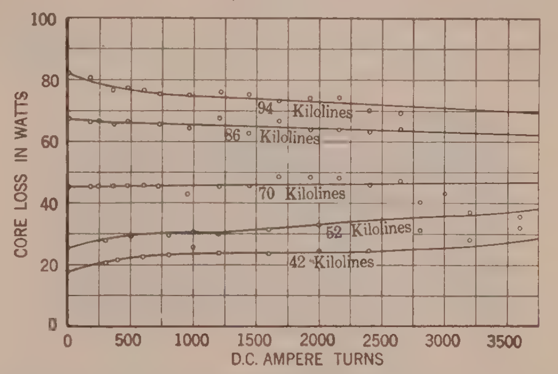

Fig. 2—Core Loss Curves for Various A-C. Flux Densities Plotted Against D-C. Ampere-Turns. Alternating and Direct Currents in Series in the Same Winding.

d-c. coils were balanced with respect to the fundamental when no current was flowing in them. If the direction of the winding is such that the a-c. voltages in the d-c. coils buck, it will be found that the a-c. flux will be *with* the d-c. flux in one core and *against* it in the other. This means that there will be a greater change of flux in one

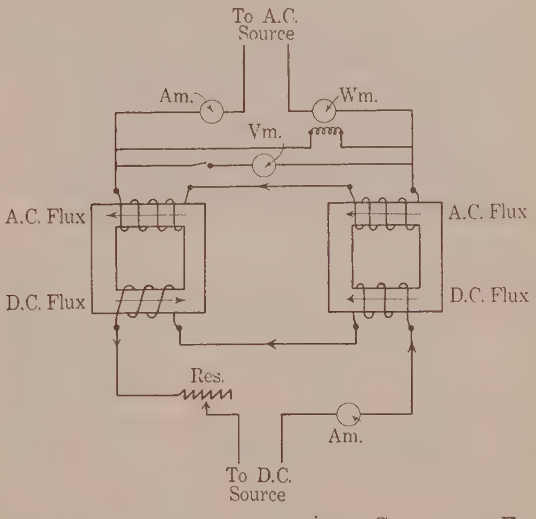

Fig. 3—Connection used in taking Curves of Fig.

core than in the other, due to the shape of the magnetization curve of iron, and hence more voltage will be induced in one coil than in the other at a given instant. This will produce a circulating current of double frequency. In fact, this is almost the identical circuit used at the Sayville Radio Station as a frequency doubler, and was first developed by Count von Arco.

When this circuit was duplicated with the identical reactors used in the work of 1923 but with an ammeter in the direct-current side that would read the square root of the sum of the squares of the r. m .s. alternating current and the direct current, and when the $I^2 R$ loss due to the circulating current was subtracted, the core loss checked that found by the simpler series circuit. At the a-c. flux density used it decreased slightly as direct current was added.

There was one peculiarity that is shown by Fig. 4. The upper line is the curve of "core loss" given in the

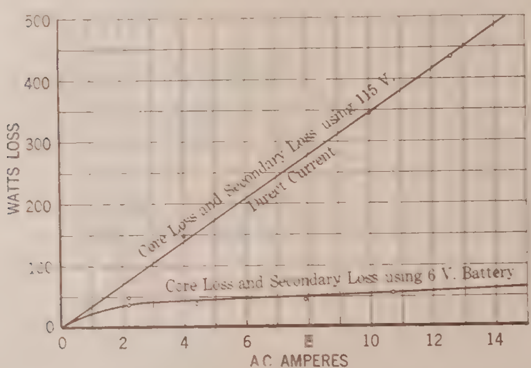

Fig. 4—Curves Showing Effect of Resistance in D-C. Circuit on Loss Due to Double Frequency Circulating Current

previous report, which really included the circulating current loss in the d-c. circuit; the lower curve is the *same thing* as read by our wattmeter. The true core loss lies under the lower curve. An explanation of the large difference is found in the different constants of the d-c. circuits. The upper curve was taken using direct current from the d-c. mains at 115 volts—a large resistance was necessary to cut it down to a value required for the windings on the reactors. In the lower curve, direct current was supplied from a storage battery of only a few cells, and a very small resistance was needed to regulate the current. In this case the second harmonic path was practically a short circuit, while in the first case it had a large resistance load in it.

It was discovered that as the resistance of the d-c. circuit was varied and the direct current kept constant by varying the voltage at its source, the circulating double frequency current remained substantially constant and approximately equal to $I_{dc}/\sqrt{2}$. This led to the suggestion that a short-circuited winding be provided in parallel with the d-c. winding in which this current could flow. This was tried and the total losses were still further decreased. The loss due to this current can be made about the same value as the iron loss without using an excessive amount of copper in this short-circuited coil. Since the r. m. s. value of the circulating current is $I_{dc}/\sqrt{2}$, if no parallel short-circuited coil is provided for the circulating current, the loss due to it will be equal to one-half the direct-current $I^2 R$ loss in the entire d-c. circuit, including the source of supply. It should be noted that any short-circuited winding should be placed next to the core in order to be most effective, as its leakage reactance will be less than if placed outside the d-c. coil.

The three-coil circuit mentioned here is shown in Fig. 5. This scheme has the disadvantage of having no d-c. flux in the middle leg of the core and consequently this flux is not so effective in changing the reactance as it might be, but the wave-form of the current is much improved by this form of core. Some core-loss curves were taken with this circuit and found to be substantially the same as those of Fig. 2, except for small differences due to the unsaturated portion of iron in the middle leg, and the increased reluctance of the direct current path. This was about three times as high as when the direct current was in series with the

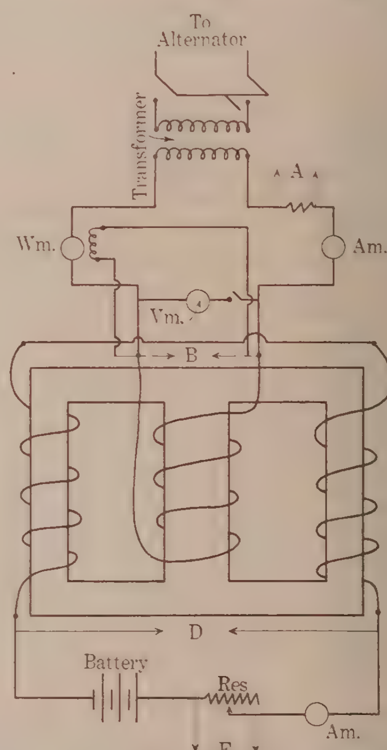

Fig. 5—Three-Coil Circuit Which Gives Better Wave Form Than the Series Circuit of Fig. 1 But Same Iron Loss

alternating current, as the area of the path was less and the length greater.

Families of curves taken at different frequencies are very similar to those shown in Fig. 2 except that they move up as the frequency is increased, much as they would if no direct current were present. The middle or straight curve comes at a higher a-c. flux density as the frequency goes up, although its actual position, the authors believe, would depend upon the relative amounts of hysteresis and eddy-current loss in the given core.

Oscillograms

Several oscillograms of the current and voltage in both the series and three-coil circuits were taken when the d-c. ampere-turns were of different values. The single-coil connection of Fig. 1 will be considered first. The addition of direct current caused the voltage wave to become quite peaked. This was due in part to the effects of the direct current on the supply transformer, as it had to circulate through the secondary of this transformer as well as through the reactor being tested. The volt-ampere load on the transformer was about half its rating when the largest value of direct current was used. The $I\,R$ drop across the regulating resistance also distorted this wave. The combined effects resulted in a flat flux wave, which in itself, would tend to cause less iron loss. That this was not the entire cause of decreased iron losses, however, will be apparent from the results of the other circuit.

The current wave with no direct current is the usual magnetizing current of iron with a high percentage of the third harmonic and other higher harmonics. When direct current is superposed, the lower half of the wave is cut off, more or less completely, depending upon the direct current value. Fig. 6 shows the voltage and current as well as the direct current alone before the alternator switch was closed. This peculiar current wave is due to the various harmonics which it contains. About 30 per cent each of a third and second harmonic, together with several higher ones, will account for this shape.

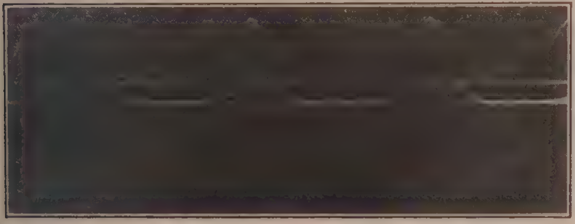

Fig. 6—Current and Voltage of the Series Circuit of Fig. 1 When Direct Current was Flowing. The D-C. Value is shown by the Upper Horizontal Line, which Was Taken Before Closing the A-C. Switch

To make sure that there was not also some valve action in the storage battery that prevented the current wave from reversing at the a-c. frequency, a battery was put in series with an alternator giving the same r. m. s. voltage as the battery, and an oscillogram taken of the current and voltage waves. The current remained sinusoidal but was displaced above the zero axis. This displaced current changed sign without any indication of a valve action, although the lower peaks of the wave just barely extended across the zero line.

Fig. 7 shows the current and applied voltage of the three-coil circuit of Fig. 5 when the a-c. flux density was about 94 kilolines, and 4000 d-c. ampere-turns were in the outer legs. There is no distortion of the voltage wave as when the direct current was in series. There is also a decided improvement in the wave form of the current, because the iron was saturated by the direct current and was operated upon the straight-line portion of its magnetization curve. Since there are two possible paths through the iron for the a-c. flux in this arrangement, the current wave remains symmetrical. The third harmonic still remaining is due partly to the unsaturated portion of iron in the middle leg, and partly to the incomplete d-c. saturation of the outside legs.

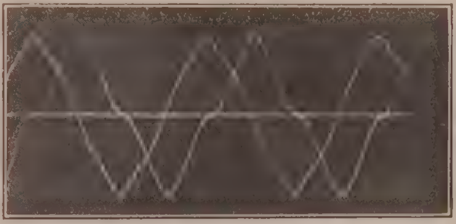

Fig. 7—Current and Voltage of the Three Coil Circuit of Fig. 5 when 4000 D-C. Ampere-Turns Were in the Outer Legs of the Core

Fig. 8 shows the current and voltage in the d-c. circuit, and the a-c. voltage applied to the middle leg. The circulating current is of just double frequency and is practically free from other harmonics.

These oscillograms are typical of the thirty or more that were taken under different conditions, and show what wave forms may be expected from a saturated core reactor.

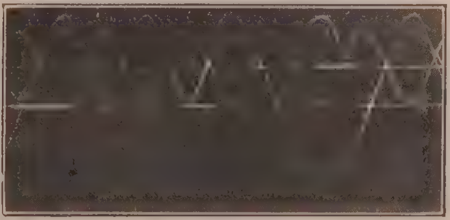

Fig. 8—Exciting Voltage (with Tooth Ripple) and Double-Frequency Circulating Current and Voltage in the D-C. Circuit. The Upper Horizontal Line is the Direct Current before the A-C. Switch was Closed, and the Double-Frequency Current is Symmetrical about this Current as an Axis

Hysteresis Loops

Dynamic hysteresis loops were taken with a two-dimensional oscillograph constructed at M. I. T. by T. W. Kenyon, and they check the wattmeter readings of core loss, at least qualitatively. There is a description of such an oscillograph by E. L. Bowles in the Journal of the A. I. E. E. for August, 1923. The instrument consists of two ordinary vibrators mounted

with their axes at right angles and the light beam is reflected by both mirrors, one giving it motion in one plane and the other deflecting it in a plane at 90 deg. to the first. One vibrator carries a shunted portion of the magnetizing current, and the other, a current which is proportional to the flux in the core. This current is obtained by inserting a very large inductance in series with an exploring coil on the core, and if the ratio of $\frac{R}{L}$ in this circuit is very small, the current is very nearly proportional to flux. If this ratio is not small, negative loops will appear at the tips of the hysteresis loop; but this effect was negligible in the circuit as used, for the ratio could be increased to four times its normal value without causing any suggestion of negative tips.

Fig. 9 shows a normal loop taken at about 94 kilolines, a-c. flux density, and one taken at the same a-c. impressed voltage, but with 8 amperes direct current flowing in the same winding. Both loops are taken to the same scale, and the area of the distorted loop does

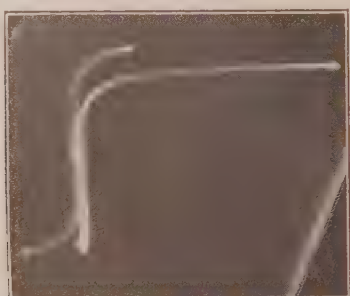

Fig. 9—Normal and Displaced Hysteresis Loops Taken with Bilateral Oscillograph. Their Area Includes Both Hysteresis and Eddy-Current Losses

not differ greatly from that of the normal one. The loop containing d-c. flux shows practically no area in the portion representing high flux density, and therefore practically no loss on this part of the cycle. The addition of direct current causes a shift to the right, of the current vibrator, but there is no effect on the flux vibrator by the steady d-c. flux in the core.

Numerous other loops were taken at various values of a-c. and d-c. flux, and an extensive study was made of the errors in the bilateral oscillograph. It is felt that the loops shown above are free from any but very small errors, and that they very nearly represent the iron loss (both hysteresis and eddy current) by their area.

However, as a further check on the accuracy of these loops ordinary oscillograms were taken of the exciting current and the voltage induced in an exploring coil on the core. Fig. 10 shows a trace of this negative. The flux wave was plotted by taking the area under the voltage wave, and the hysteresis loop was constructed from this flux wave and the current wave. The constructed loop checks the distorted loop of Fig. 9 very well indeed, if allowance is made for the difference in scales. The applied d-c. voltage and direct-current values were the same in both cases.

Fig. 11 shows two loops taken with the three-coil circuit. The flux vibrator was connected to an exploring coil of five turns wound outside of the main coil on the middle leg. The current vibrator carried a part

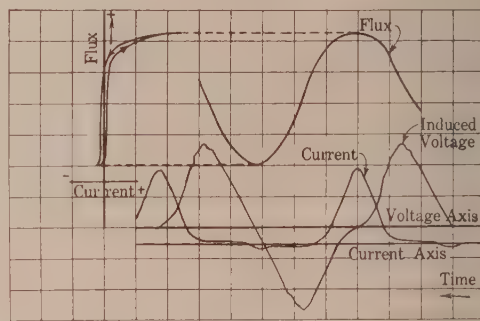

Fig. 10—Displaced Hysteresis Loop Constructed From Actual Current and Voltage Waves. Note that this Loop is Substantially the Same as the One taken with the Bilateral Oscillograph

of the exciting current shunted off at (*a*) in Fig. 5. The currents were so high that the errors due to leakage and $I R$ drop were very pronounced. The area of the loop is actually negative, and is, therefore valueless in indicating losses. It does show the change in permeability, though, by the decrease in its slope when the direct current was added. The vertical loop is a normal one, and has very little error, since the exciting current was quite low when no direct current was present. The

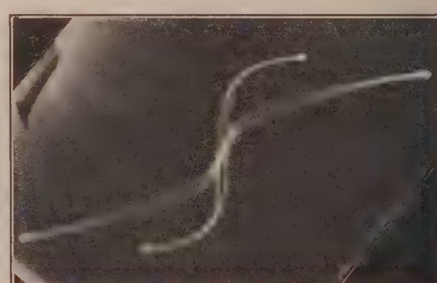

Fig. 11—Normal and Displaced Hysteresis Loops of Three Coil Circuit of Fig. 5, Showing Change in Impedance by a Decrease in Slope when Direct Current is Added. Area of Distorted Loop is not Representative of Iron Loss Because of Errors

distorted loop shows the effect of leakage and $I R$ drop at high values of d-c. flux by a decrease in vertical height. The exploring coil did not link as much of the flux when the core was saturated, and the flux was less by the $I R$ drop, since the applied voltage was held constant. It should be noted that the average slope of the whole loop from the horizontal axis is a measure of

the a-c. permeability of the iron, or impedance of the reactor.

Impedance Curves

The design which gives the greatest change in impedance for the least number of d-c. ampere-turns is the best, other things being equal. Fig. 12 shows the change in impedance of the reactor as direct current is added. All of these curves are at 60 cycles. In each case the impedance, when there is no direct current, is taken as 100 per cent and the percentage of this impedance plotted for different d-c. ampere-turns. Curve No. 1 is at a low a-c. flux density (42 kilolines) and has the direct current in series (only the center leg of the reactor being used). The initial decrease in impedance

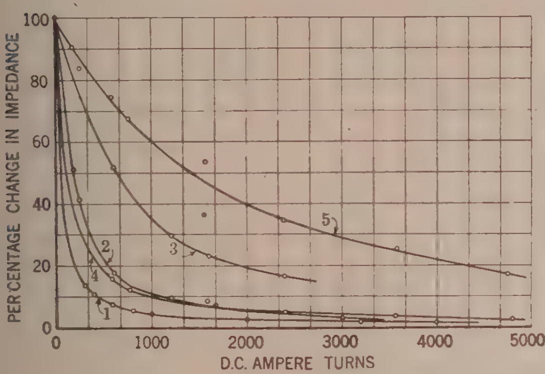

Fig. 12—Percentage Change in Impedance of Reactor with an Increase of D-C. Excitation for Various Connections and Different Values of A-C. Excitation

is seen to be quite large for small values of direct current. No. 2 is the same curve for 70 kilolines, and No. 3 for 94 kilolines. The direct current is most effective at low a-c. flux densities. Curve No. 4 is also at 42 kilolines, but has direct current in the outside legs only. It lies above Curve No. 1 because the middle leg is not affected by the d-c. flux, and the reluctance of the d-c. path is higher than for the series connection. No. 5 is at 90 kilolines and corresponds to No. 3 of the series circuit.

Conclusions

The results of this work indicate that the *iron losses* of a d-c. excited reactor are not excessive. For high a-c. saturations, such as would be used in shunt reactors for voltage regulation on a transmission line, the iron losses proper, may even be decreased. However, no scheme has yet been discovered for eliminating the necessary evil of the double frequency circulating current, and its copper loss must really be charged up to the iron. This loss, however, may be made as small as desired by using sufficient copper, since for a given core the double frequency current is a function of the direct current excitation, and by its circulation, tends to cut down the voltage that produces it. Its limiting peak value is the value of direct current if it all flows in the d-c. circuit.

In conclusion, the authors wish to express their appreciation to Dr. V. Bush, for his inspiration and assistance during the course of the work and to Messrs. G. Faccioli, A. Boyajian, and O. R. Schurig, for their helpful criticisms and suggestions.

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WORLD POWER CONFERENCE

At a meeting of the International Executive Committee of the *World Power Conference* held in London, July 27-30, an invitation was presented by Dr. E. Tissot on behalf of the Swiss National Committee to hold the Second World Power Conference at Basle in 1926. It was considered advisable, however, to allow a longer period to elapse between plenary sessions. In the interval sectional meetings might be held, and it was decided that such a meeting should be held in Basle next year. The subjects recommended for consideration include the development of hydroelectric power combined with navigation, the financial and legal aspects of inter-exchange of electric power between countries, the economic relation between water power and thermal power, electricity in agriculture, and railway electrification. It was decided that, subject to reconsideration, the Second World Power Conference should be held in 1930.—*World Power.*

Live Problems in Connection With Protection of Electrical Systems

By Committee on Protective Devices[1]

IN accordance with a practise established over a number of years, the work of the Committee on Protective Devices has been delegated to a number of subcommittees, the division being made with reference to the nature of the subject covered. Complete reports from each of these subcommittees are appended.

It will be observed that one new subcommittee is reporting in addition to those reporting last year. By a ruling of the Board of Directors, the subject of automatic substations was assigned to the Committee on Protective Devices. The work of this subcommittee has been done in cooperation with other committees, covering the apparatus used in automatic substations, and while the report deals particularly with protective devices, it will be found to cover rather completely the situation in automatic substations as found today.

It is felt that the scope of work assigned to the Committee on Protective Devices is very well covered by the activities of the following subcommittees and the Chairman would not suggest any radical change in the organization as it now exists. It is heartily recommended, however, that the work begun by these various subcommittees be continued during the coming year and that the recommendations made in each case be followed.

Automatic Stations

Fundamental Difference Required in Design of Devices for Automatic Application from those for Manual Application

One of the things which differentiate devices used in automatic stations from those used in manually-operated stations is the question of inspection. The designers of devices for manual stations tacitly assume that all of the devices will either be continuously under the eye of an attendant or will be inspected several times each day. This tacit assumption is borne out by the fact that the usual manual station is provided with instruments and switches. A human intelligence is required to read the instruments and thus operate the switches in accordance with the story told by the instruments. As a result, the designers of devices for manual stations have paid more attention to the performance of the devices in response to a specific circuit condition than to their continued successful performance with inspections at intervals exceeding a week.

Another item differentiating the design of devices for automatic stations from those in manual stations is the relative life to be expected from the two. Devices for automatic stations require in some instances a successful life of several million operations. The only devices in manual stations called upon for similar services are probably the automatic generator-voltage regulators and some of the control apparatus used for steel mill service. In each of these latter cases, life has been an important feature of the design and as much attention has been paid to this as to the operating characteristic of the devices.

It will be seen, therefore, that primarily the attitude of the designers of devices used in manual stations contemplates an attendant who will supply any deficiencies in the operation of the devices, while the design of devices for automatic stations requires that the devices function correctly or else make the station inoperative.

Minimum Safe Protection for Power Apparatus in Automatic Substations

From the standpoint of railway applications, the amount of protection that is afforded automatic substation equipment by the use of various devices, relays, etc., is a direct function of the type of installation with respect to its application, importance and whether full-automatic or partial-automatic.

This statement may be amplified by considering a typical case. It is the installation of automatic equipment on large urban properties where the successful and continued operation of the substations is of prime importance. Here it is customary to install all the various types of protection that will prevent, as far as possible, either an interruption to power service or damage to equipment.

On the other hand, automatic substations installed on some small interurban or suburban railways do not require the refinements of protection afforded more important substations. This is due, in some cases, to lack of capital for initial investment. In other cases the continuity of service is not the controlling factor and the protective features may be kept to a minimum. These substations quite frequently take the form of the so-called partial-automatic type where an attendant or a

1. Annual Report of Committee on Protective Devices.

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G. H. Bragg,	George S. Humphrey,	W. H. Millan,
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R. A. Hentz,		A. H. Sweetnam.

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y., June 23, 1925.

time clock is used to start and stop the station. Upon the occurrence of trouble these substations are generally arranged to cease operation and remain out of service until restarted by an attendant.

For standard size 600-volt converters, feeding into a metropolitan railway-distribution network, the following minimum protection is recommended:

A-c. overload (lock-out); d-c. overload; sustained overload; a-c. undervoltage; d-c. reverse current overheating of current limiting resistors; failure of field circuit; overspeed (lock-out); overheating of bearings (lock-out); failure to complete starting cycle (lock-out); flashover (lock-out).

D-c. Edison-system automatics are called upon for a high class of service and the protective features must be so chosen and applied that the service must be maintained. There is a tendency at present to so protect the station that the machines are tripped off at times when the condition of stress may be far below the limit of the machine. This has had a tendency to prejudice prospective purchasers of automatic apparatus by apparently complicating the switching equipment.

It has been the practise in some heavy manual systems to tie the converters or motor generators solidly to the bus without protection on the d-c. end. Within reasonable limits it is felt that this could be approached in the design of automatics on the same class of system.

For 250-volt motor-generator sets and converters the following minimum protection is recommended:

A-c. overload (lock-out); d-c. overload; sustained overload; overheating of machine; overheating of transformer; overheating of current limiting resistors; a-c. undervoltage; d-c reverse current; overspeed (lock-out); failure to complete starting cycle (lock-out); overheating of bearings (lock-out); flashover (lock-out).

Various devices for the protection of the service may be applied; in fact it is felt that this feature cannot be overdone. Several equipments have temperature protection which reduces the load on the machine upon the temperature rising within a few degrees of the point at which the set would be taken off of the system. In this way the system voltage is held somewhat above the value which would obtain if the over-temperature device disconnected the machine from the system. In most cases the machine will cool while operating at partial load. As practically all machines are arranged to limit their output by means of regulating devices, the overheating is usually caused by inadequate ventilation or a failure of ventilating apparatus. If the ventilation is only partly retarded by the failure, the machine would probably operate indefinitely at partial load; the voltage, of course, being somewhat low but at least some power being delivered to the system. The liberal use of thermostats, operating alarms over supervisory circuits in the Dispatcher's Office, will protect the service to a large extent. An attendant may be dispatched to the station upon indication of even slight over-temperature and may be able to alleviate the trouble in time.

Automatic A-C. Distribution and Transformer Stations

The protection to the service should consist of reclosing features applied to the outgoing circuits. Power supply to the station should be assured by proper overload, balanced, or reverse-current protection of the parallel transmission lines supplying the station, or by automatic transfer devices if not desirable to have transmission circuits paralleled. Differential protection should be provided for each transformer so that a defective unit will clear from the system without interruption to service. The matter of apparatus protection may be reduced to that of transforming and regulating devices; their protection should be against overheating and groundings. All outgoing circuits should, of course, be provided with overload protection and in cases of automatically reclosed circuits, lock-out features should be provided.

Oil Circuit Breaker Operating Duty as Applied to Automatic Reclosing Circuits

It is suggested that an attempt be made to get the manufacturers of switchgear to furnish ratings with oil breakers supplied for this class of service that will enable the operating engineer to apply intelligently these breakers to his circuits which are to be reclosed after tripping on trouble. Referring to distribution circuits in the 2200- to 6600-volt class, it seems to be general practise to reclose these circuits three times before final lock-out. There seems to be a little difference of opinion here and there as to just how much time should elapse between reclosures, but as a general average we might say that the first reclosure is made in from two to five seconds after tripping; the second reclosure in about 30 seconds from zero, (initial tripping) and the third in anywhere from 60 to 180 seconds from zero. It is felt that if the manufacturers were to establish a tentative standard somewhere near the above values and rate the breakers on this basis, that the operating companies would either accept the standard or their own idea of the values would be close enough to the standard to make an intelligent application. Even if this tentative standard were based on three or four reclosures at five-second intervals it would be a decided advantage over what is now available.

Nomenclature for Types of Automatic Reclosing D-C. Feeders

The following is suggested:

A. Types of Feeders

1. Stub Feeder. A Stub Feeder is one which, at the time of reclosing, receives energy for the testing circuit from one source only.

2. Multiple Feeder. A Multiple Feeder is one

which, at the time of reclosing, receives energy for the testing circuit from two or more sources.

3. Stub-Multiple Feeder. A Stub-Multiple Feeder is one which, at the time of reclosing, may receive energy for the testing circuit either from one, two or more sources.

B. Methods of Automatic Test Prior to Reclosing

1. Continuous Testing by Current. Continuous testing by current is a method which continuously furnishes to the feeder a limited current which operates a device or devices adjusted to function at or below some predetermined value of current flow into the feeder to effect reclosure of the circuit interrupter.

2. Intermittent Testing by Current. Intermittent testing by current is a method which intermittently furnishes to the feeder a limited current, operating a device or devices adjusted to function at or below some predetermined value of current flow into the feeder to effect reclosure of the circuit interrupter.

3. Testing by Voltage. Testing by voltage is a method which employs a voltage-actuated device connected between the source of energy and the feeder or between two sources of energy to effect reclosure of the circuit interrupter at a predetermined voltage condition.

Remote Supervision

The handling of various switching and receiving indications of operations from remote points has received much attention. The larger operating companies are discovering that, even with manual switching, something of this nature is necessary to expedite operations in times of trouble. As soon as a system grows to a size where it becomes necessary to establish a central dispatcher to direct switching, it is at once manifest that when trouble occurs, the switching necessary to bring the system to normal can be carried out only as fast as the dispatcher can obtain information. The use of the telephone for this involves the chance of human error and retards action as an operator cannot manipulate his switchgear while telephoning. The use of supervisory systems to provide the dispatcher immediately with an indication of changed condition shunts out many minutes of valuable time. In automatic stations, indications may be given of almost anything required and it becomes only a matter of how far it is desirable to go in a given case. In Edison system automatics, remote supervision is particularly helpful as there are many conditions which can occur without warning and if allowed to continue may result in partial service interruption. For the dispatcher to feel that he has his system well in hand he should have at least the following indications from each of his Edison system automatics.

1. Continuous indication of d-c. amperes on each unit in the substation.
2. Positions of all oil circuit breakers.
3. Alarm upon failure of ventilating system.
4. Alarm when predetermined high temperature value is reached at the air discharge from any unit.
5. Alarm upon the operation of the lock-out relay on any unit as he may not otherwise know that the machine will not restart upon demand.

He should also have sufficient supervisory apparatus to enable him to shut down and "hold off" any or all units so that he may, if desired, restrict the output from a given station. In addition to the above it may be desirable, although not necessary, to have supervision over the closing and opening of the oil breakers on the supply feeders and junctions in the supply bus, etc.

Supervision of a-c. distribution automatics is, of course, less elaborate due to the simple nature of the equipment in such stations. There are comparatively few indications that the dispatcher really has any use for and the balance is rather a matter of convenience.

It is sometimes desirable for the dispatcher to know when the lock-out relay on any of the automatically reclosed circuits has operated, although it is not necessary for him to be able to release the lock-out as it is generally necessary to make repairs before the circuit is again closed. It is observed in some communities that sufficient trouble calls from customers pile up in two or three minutes to indicate definitely that the whole circuit is dead and therefore, before the dispatcher can inform the proper persons in the Trouble Department of his supervisory indication, they have already made their deductions.

It is sometimes desirable to give the dispatcher control over the breakers in the incoming supply lines but it is better engineering to arrange them to take care of themselves.

In special cases where water-cooled or air-blast equipment is used, it is almost necessary to give the dispatcher a warning of the failure of the auxiliary apparatus involved but in average cases such detail is not met with. A-c. distribution stations are usually in outlying sections and at a considerable distance from the center of operations. In this connection the matter of rental of telephone pair mileage becomes quite an item of cost.

In general, a supervisory system is a very desirable asset to a system but it should never be forgotten that the reliability of the whole scheme can be made no better than the wires used in the circuit—experience has indicated that it is impossible to maintain 100 per cent service on such small circuits. The station should be arranged, if possible, to take care of all conditions automatically without the aid of the remote supervision.

Load-Limiting Schemes in Event of Overload (D-C.)

Load Limiting by Series Resistance (Fig. 1). Load limiting by successive steps of series resistance in the main circuit is probably the oldest type of load limiting scheme used in automatic stations. It is applicable to

synchronous converters and all types of generators. For this scheme the d-c. machine is connected directly to the negative. The positive is connected to the bus through a group of series resistors and a line contactor or circuit breaker. The usual design uses three steps of load limiting resistance with one shunting contactor or breaker for each step. The d-c. machine is connected to the bus with the shunting contactors open. Then the shunting contactors are closed successively;

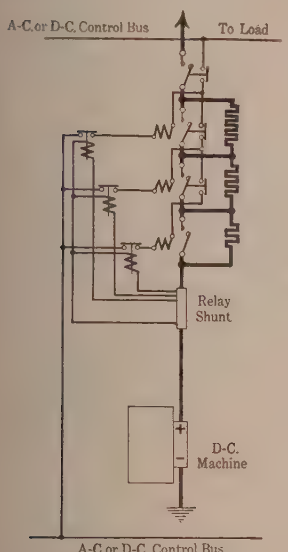

Fig. 1—Load Limiting by Steps of Series Resistance in the Main Circuit

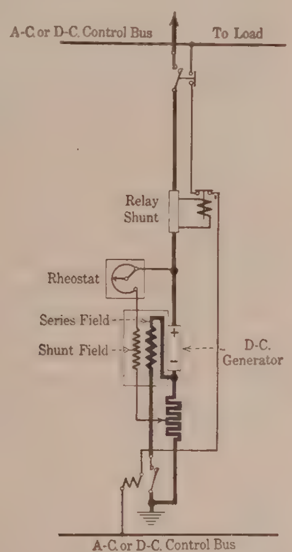

Fig. 2—Load Limiting by Accumulative Series, Field-Shunting Resistance

thus gradually making the bus and the machine pressures equal.

In case of overload, one or more steps of resistance are inserted into the line. If all the steps of resistance are inserted by means of the magnitude of the overload and if this overload persists for long enough time to overheat the resistors, then a thermal relay opens the line contactor and the machine is disconnected from the load until the load-limiting resistors cool. After they have cooled, the machine is again connected to the bus through the resistors which are gradually shunted out, if the load permits.

Suitable interlocking is provided between the contactors to insure the correct sequence for closing and for opening.

Load Limiting by Accumulative Series Field Shunting Resistance (Fig. 2). Load limiting by accumulative series, field shunting resistance is used almost exclusively in connection with compound wound d-c. generators. The scheme is applicable with additional load-limiting resistors such as described above. It is permissable to eliminate such series resistors, however, if the characteristics of the load and the machine are within certain limits.

During normal operation the series field-shunting resistor has only a slight effect in reducing the amount of compounding. On overload a contactor is opened and this causes:

1. The generator to become a shunt machine.
2. The shunting resistance to be inserted in series with the machine.
3. The shunt field to be reduced due to voltage drop through the series field-shunting resistance.

On reduction in load to a predetermined value, a relay recloses the overload contactor as in scheme No. 1. Also, as in the previous scheme, interlocks are provided between the contactors to insure the correct sequence of opening and closing.

Load Limiting by Counter E. M. F. Generator (Fig. 3). Load limiting by counter e. m. f. generator is particularly applicable to shunt-wound generators. This scheme employs a small motor-generator set with the armature of the generator in series with the shunt field of the main generator. The small generator has two shunt-field windings. One is a comparatively weak boosting winding. The other is a stronger bucking winding. The boosting winding is used to supply a constant and practically separate excitation. The bucking winding is used to reduce the shunt field current of the main generator when it is inserted in the circuit by the opening of the contacts of a relay on overload.

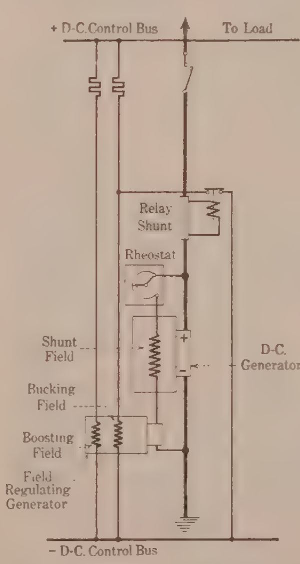

Fig. 3—Load Limiting by Counter E. M. F. Generator

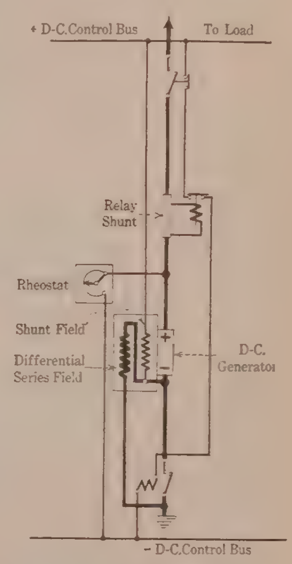

Fig. 4—Load Limiting by Differential Series Field

The load is held at the setting of this relay by the regulating action of its contacts as long as the external circuit conditions require.

An excessive overload on the machine is prevented by control of the machine voltage up to a certain definite load beyond which the constant current relay in combination with the counter e. m. f. regulator makes the machine practically constant current.

Load Limiting by Differential Series Field (Fig. 4).

Load limiting by differential series field is applicable to direct current generators provided with a series field connected differentially. During normal operation, a contactor short circuits the differential series field. On overload, reverse current or short circuit, this contactor is opened by a suitable relay combination and thus inserts the differential series field into the circuit.

This method of load limiting is usually employed in conjunction with voltage and load regulating schemes, including a motor-operated shunt-field rheostat. Stability of operation on the differential series field characteristic is obtained through a constant amount of excitation from the d-c. control bus.

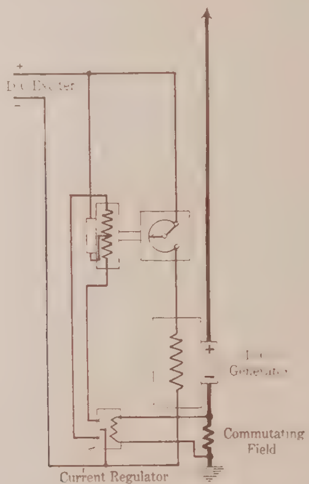

Fig. 5—Load Limiting by Current Regulator Controlling Shunt Field Rheostat

Load Limiting by Motor-Operated Field Rheostat (Fig. 5). Load limiting by motor-operated field rheostat is probably the simplest of all of the schemes employed. It is applicable particularly to d-c. generators and is suitable in general only for machines with separate field excitation, to insure stability at all voltages.

Essentially the scheme consists of a contact-making ammeter or current regulator with a certain floating range. This device controls a motor-operated shunt-field rheostat which is operated to maintain definite voltage up to a certain load and then to reduce the voltage in order to back off from the load in case the load exceeds a certain given value.

Load Limiting by Step-Induction Regulator (Fig. 6). This scheme is applied to the transformer of a synchronous converter and affects the performance of the converter in the same manner as the well-known scheme of introducing an induction regulator between the a-c. supply and the rings of the converter, either ahead or behind the transformer. The old scheme, for various reasons, was limited to about 20 per cent range in voltage at the d-c. terminals of the converter, while this scheme is limited only by the ability of the converter to perform in a stable manner at low voltages. This limit is somewhere under 50 per cent of the rated voltage of the converter. The scheme consists essentially of an extended winding on the primary of the transformer with taps brought out at intervals. By means of a series of tap-changing switches coupled mechanically to an induction regulator, the steps of the winding are brought in or out of circuit. The various transitions are made at zero current in the tap-changing switch, the induction regulator acting as a booster to equalize the two points which are to be momentarily tied together during transition. The d-c. regulating range of the converter resembles a smooth curve. This scheme permits the use of a standard shunt-type converter, which is inherently a very stable machine.

Automatic Fire Extinguishment and Detection

Very little of a practical nature has been done along these lines except in power-plant work where the automatic liberation of inert gases into generator-cooling air has been more or less successfully carried out. There seems to be only two forms of extinguishing media which might be applied to automatic stations; inert gas and chemically-formed foam, the bubbles of which contain an inert gas. The objection to inert gas is the necessity for automatically closed dampers that will

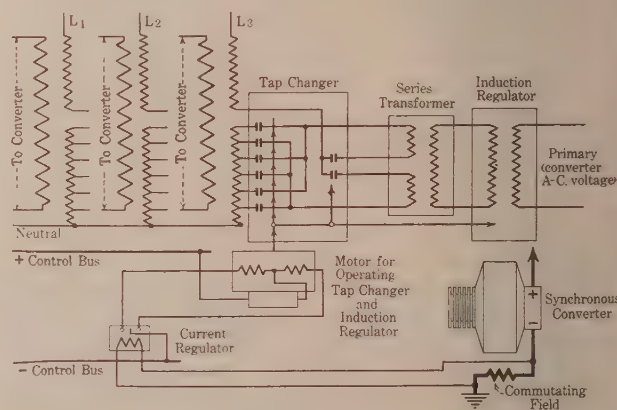

Fig. 6—Load Limiting by Step Induction Regulator in Transformer of Converter

be tight enough to retain a sufficient amount of the liberated gas in the space affected. This method can best be applied to small stations using forced ventilation, as the whole station may be drenched with gas by closing the dampers at the intake and discharge openings. Stations provided with natural ventilation only are usually provided with a large number of openings both for intake and discharge and the problem of damper control would probably be too difficult. It is felt that this type of station, which is usually large in cubical capacity, can best be protected by the foam method, either in unit sections or by a system of sprinkler pipes. In this connection some experiments have been made in the application of a foam unit to a compartment or stall housing an induction regulator. The

foam tank was suspended over the regulator and by means of a standard fire fuse, the chemicals were liberated into the tank where their mixing produces the foam. A section of the tank bottom was arranged to allow the foam as it was produced to drop down upon the body of the regulator. The effect produced was to cover the regulator with foam. In order to completely blanket the regulator it was necessary to close the open side of the stall with a screen which even of large mesh (½ in.) will cause the foam to be retained in the compartment. While this scheme indicated at least one good way of preventing a spread of fire from a regulator failure, it was felt that it could not always be applied in just this way. Fires generally originate in windings and except in cases of rotating equipment the devices possessing these windings may be installed in compartments or perhaps a group of such devices in an isolated chamber. This compartment or chamber may be protected by a foam unit or if the ventilating arrangement is just right by a gas unit. It was realized that wherever foam was used some method of heating the chemical tanks would be necessary to prevent freezing. A scheme was worked out for the protection of a compartment by gas where the nature of the device in the compartment was such as to necessitate one side of the stall being open for ventilation (this typical case being applied to an induction regulator). The use of the standard-roller, steel fire-curtain door was not thought advisable on account of its high cost and the fact that it was metal. A door of asbestos lumber, hinged at the top corners, was worked out. The door itself was hinged in the middle so that it could be hooked up to the ceiling in front of the compartment, jack-knife fashion. The operation of the fire fuse over the regulator released the gas supply and the door trigger at the same time, thus permitting the affected compartment to be flooded. It is necessary of course that an excess of gas be liberated in the stall as this type of door will have considerable leakage around it. It is felt that the use of the above door, even without liberating an extinguishing agent, would be a step in the right direction and incidentally cheap enough to justify its use.

The matter of automatic fire detection has been given much thought. It is not very desirable to attempt to detect fire by temperature for more than one reason. First, the ordinary fire fuse used for building sprinkler systems has been known to liberate water when no fire has occurred at all. This sort of performance is, of course, unthinkable in automatic substations. Secondly, a fire such as we may experience first manifests itself in an odor followed by smoke and last by violent temperature rise. The most desirable thing to use to give the alarm would, of course, be the presence of a strong odor but as no automatic "smelling" devices have been produced, it is obviously impossible to consider this. Smoke, however, can be detected automatically and at present there is actually available a system, which by means of small suction pipes from various vital parts of a building, continually "samples" the air from these parts. This system is in use on shipboard and the indicating cabinet is located where some delegated officer can continually observe it. The smoke is made clearly visible by means of a properly directed light beam. It remains only to cause these light beams to act constantly on suitable devices to obtain automatic detection. This system in its present state of development is very elaborate and it is doubted if it can be justified in automatic stations at least for the present, but the manufacturers have indicated a desire to develop it further in the hope that it may be the answer to a good many of their problems.

Reactors

Since the most important feature of a current-limiting reactor is its reliability, the subcommittee has continued the collection of data on failures. The few reactors that have been called to its attention are mostly of the older design and the small number indicates that even in these, the weak points have been practically eliminated. Such failures which have occurred serve to keep before the manufacturers of reactors and engineers of power stations, the need for the greatest care in their manufacture and installation to the end that failures will be reduced to a minimum.

It is generally agreed that for medium and large size systems, reactors are a necessity not only because they reduce short-circuit currents and thereby lessen the duty on oil-circuit breakers and the electro-magnetic stresses on all equipment, but also maintain voltage on the rest of the system in the event of heavy short circuits in any one section of it. Were reactors omitted it is probable that an equal or greater cost would be involved in providing and installing oil circuit breakers of sufficient rupturing capacity to successfully open the very heavy short circuits that could flow, if indeed such oil circuit breakers could be built at the present time, and the system would still be without the stabilizing effect which reactors give.

Reactors being a protective device may be considered a form of insurance for which large premiums are paid in the form of losses and even more costly capital expenditures. Indicative of the extent of these capital expenditures is the fact that in one 200,000 kv-a. plant, the reactor installation (including compartments, building space, etc.), represents 15 per cent of the cost of the switchhouse. Another company, in order to add feeder reactors to one of its older plants, has had to erect a separate building for this purpose.

Thermal capacity continues to receive attention and the subject is being further investigated. There has been a distinct tendency towards increased copper cross-section. One operating company has increased the conductor size of its 3 per cent feeder reactors more than 100 per cent over that used about ten years ago, this increase being due to a desire for greater

factor of safety, rather than the slightly greater duty imposed by the system's growth. The increased cost is but a small part of the total.

The smaller cross section of these older coils should receive the careful attention of all operating men. The increased use of reactors on outgoing feeders from substations offers a means of using these older coils advantageously, the newer coils being installed in the generating stations, where the short-circuit currents as well as the importance is usually less.

One or two operating companies have found it advantageous to order reactors with taps, so as to properly load parallel feeders of dissimilar characteristics (due to size or length, or both).

Recently attention has been focused on shielding the reactor leads so as to prevent damage from foreign magnetic material, such as bolts, nails, etc., from being accidentally dropped into the coils or drawn into them at times of short circuit. One American manufacturer has enclosed the coils in porcelain and in England a similar protection has been used. Another American manufacturer has designed coils with asbestos insulation around the copper conductors to avoid having the bare parts exposed to this danger. The committee expects to keep in close touch with this development.

The extension of the use of reactors is of interest. At first used in generating stations where their need is, of course, greatest, they are now being installed in substations on lines operating at generator voltages and also on the 2300- and 4000-volt distribution circuits. This latter application not only reduces the duty on the oil circuit breakers (a desirable step, especially where automatic circuit reclosing is employed), but also on the induction regulators, which on many systems would otherwise be subject to short circuits greater than those they are able to withstand.

At the last Annual Convention of the Institute, papers by Boyajian and Blake were presented on a new form of current-limiting reactor—the saturated core type. The coils are wound on an iron core and the superimposition of a constant unidirectional flux (from coil-carrying direct current) gives a coil with low reactance on normal loads but high reactance at times of short circuit. The cost of such a coil will probably limit its use to special applications.

A paper on "Eight Years Experience with Protective Reactors" was presented before the Spring Convention (St. Louis) of the Institute by Lyman, Perry and Rossman.

In addition to points touched upon above, the Committee recommends that the succeeding Committee give consideration to two points which have recently been suggested, namely:

The question of the use of current-limiting reactors with static condensers, to—

1. Aid in smoothing out surges.
2. Limit the fuse current.
3. Increase the capacity of the condenser.

The question as to whether the use of reactors actually increases the duty on oil circuit breakers.

Grounding of Systems

The principal activities of the subcommittee this year consisted in summarizing the information on grounding methods received in reply to an inquiry sent out in conjunction with the corresponding subcommittee of the National Electric Light Association, to thirty representative companies in the United States.

This subcommittee confined its study to the technical information gathered in this survey, paying particular attention to grounding methods used in a-c. substations of systems transmitting at higher than generator voltage. The prevailing practise of this class of systems is to dead ground the neutral, consequently in case of line to ground faults, large values of ground currents must be taken care of, which calls for a careful study of grounding methods.

The great increase in size of a-c. substations in recent years has forced attention to proper methods of grounding, because in large capacity substations ground fault currents attain such magnitude, that even when flowing through ground connections of only a fraction of an ohm will produce dangerous voltage gradients. In general, it may be stated that the problem of grounding is not so much that of obtaining individual grounds of low impedance, but rather one of obtaining a well distributed ground so as to approach an ideal equipotential area and thereby avoid dangerous potential gradients near ground electrodes when ground-fault currents flow. Another important requirement for a successful ground is the ability to dissipate, at times, large amounts of energy without a material change in the ground.

Grounding to Water Piping System. Water piping systems afford the best grounding systems obtainable and should be used wherever the necessary permission can be obtained. In fact, water systems have such comparatively low ground resistance that, where they are in proximity to other artificial grounds, a difference of potential will exist under fault conditions which will constitute a hazard to life unless the two are connected together. Unfortunately, water systems are available only in built up districts and generally can only be taken advantage of by indoor and moderate voltage substations.

Artificial Grounds. At high-tension substations in outlying districts, it is generally necessary to resort to artificial grounds such as plate or pipe grounds. It is interesting to note that the tendency is away from the use of plate grounds and toward the greater use of pipe grounds.

Although a single pipe ground has a higher resistance than a single plate ground, a pipe ground of low resistance can be obtained by multiple grounding, that is, by connecting numerous pipes in parallel. In this way

a ground of a given resistance can be obtained more economically with pipes than with plates. In addition, the multiple pipe ground will have the advantage of providing a well distributed ground which, as pointed out above, is a very important requirement. It may, therefore, be stated that the advantage of pipe grounds over plate grounds are that they:

a. Are more economical.

b. Are more easily installed.

c. Allow for convenient inspection and test.

d. Provide a distributed ground over considerable area when used in multiple.

The characteristics of ground pipes have been definitely determined in extensive tests conducted by the Bureau of Standards and others. Quantitative values on the properties of ground pipes may be summarized as follows:

a. The decrease in resistance with increased size of pipe is quite appreciable up to a pipe one inch in size, beyond which the curve becomes quite flat. From the standpoint of resistance there is, therefore, no economy in using pipe sizes larger than one inch.

b. Very little decrease in resistance is obtained by driving pipes to a greater depth than six feet. Pipes should, of course, be driven to a greater depth when the permanent moisture level is at a greater depth than this.

c. Ninety per cent of the resistance of a pipe ground falls within a radius of six to ten feet around the pipe. Pipes should, therefore, be spaced approximately six feet apart to keep one out of the dense current field of the other.

The effect of moisture and temperature on the resistivity of soils is surprisingly great below certain limits. Above a moisture content of 20 per cent there is very little variation in coil resistivity with variation in moisture content. Below a moisture content of 20 per cent, the resistivity rises very abruptly. With a moisture content of only 10 per cent, the resistivity of red clay soil is 30 times as great as with a moisture content of 20 per cent.

The effect of temperature on resistivity of soil is not appreciable above 32 deg. fahr. Below the freezing point, however, the resistance increases very rapidly, being 50 times as great at a temperature of 5 deg. than at 32 deg.

In arid regions and in localities with sandy and rocky formations it is generally very difficult to obtain a good ground. In the West where such difficulties are frequently encountered, satisfactory grounds have been obtained by grounding to the steel casings of deep wells. Much benefit can also be obtained by treating the soil surrounding electrodes with chemicals such as ordinary salt, because, of the total resistance of a ground connection the most important part is contributed by the soil, the resistance of the electrode and contact resistance between electrode and soil under ordinary conditions being negligible. The electrical conductance of any soil is by means of the electrolytes formed by moisture combining with the soluble acids, alkalies, and salts, and where they are lacking, their artificial introduction will show excellent results. Such artificially treated soils require close attention and inspection as chemicals must be removed from time to time.

Potential Gradients. Because of the importance attached to the subject of potential gradients near ground electrodes, several tests were made to determine their values under normal operating conditions. These tests, which are reported in Appendixes A and B show that at least 50 per cent of the total voltage drop of a ground will fall within two feet of the ground electrode.

As reported in Appendix A, the potential gradient near the transmission tower when a line conductor becomes grounded to the tower is great enough to constitute a hazard to life. In this case the towers were near a highway and it was recommended that overhead ground wires be installed and carried back to the station ground, so as to improve grounding conditions on the line and eliminate potential gradient hazards.

In the test reported in Appendix B, heavy currents were used which, by heating and drying out the ground caused 80 per cent of the total voltage drop to fall within one foot of the ground electrode. This test emphasizes the importance of making ground connection capable of dissipating large amounts of energy without changing the character of the ground.

Value of Overhead Ground Wire. As pointed out in Appendix A, the overhead ground wire assists materially in reducing line and system ground resistances by connecting all tower and substation grounds in parallel. Several companies report improvement in relay action on grounded systems by connecting station grounds to the overhead ground wire on transmission lines. One company which formerly terminated overhead ground wire one or more spans away from substation reports that serious potential gradients were produced by returning ground currents when lines became grounded to towers, which hazard was eliminated by connecting the overhead ground wire to the substation grounds. It is evident, therefore, that in order to obtain the full benefit of overhead ground wires, they should be connected to the station grounds.

Petersen Earth Coil. Eleven months additional operating experience with the Alabama Power Company's Petersen Earth Coil is reported in a paper by J. M. Oliver and W. W. Eberhardt. The additional experience indicates that the high-voltage disturbances which were experienced when the coil was first placed in service have been entirely eliminated by making provisions to do all line switching, both hand and automatic, with the coil out of service—that is, with the system neutral solidly grounded.

From the experience to date, the application of Petersen Coils appear to be limited to comparatively low voltage lines (66,000 volts and less) of moderate length with a single source of power supply. On an

interconnected network, where several sources of supply are maintained to all principle load centers, good service can be maintained without the use of flashover suppressing devices. In other words, the expense and complications of a Peterson Coil installation are justified only on radial feeder systems where it is desired to improve service to an important load center which is connected to the power source by only a single line. The Petersen Coil in such an application has the advantage over grounded neutral operation by reducing line outages due to flashovers, and over isolated neutral operation by eliminating arcing grounds.

Grounding at Generating Stations for Proper Functioning of Relays. In isolated phase installations, although the possibility of phase to phase short circuits are eliminated in case of two simultaneous faults to ground, the hazard of a fault to ground still remains.

Investigations have been made to determine the possibility, not of preventing ground fault currents, but of directing them into channels where they may be taken care of by connecting all metal parts, which are not normally at line potential but which are separated from parts at line potential by insulation, to a copper grounding system. The grounding busses of the three phases are joined together and taken through a current transformer to the station ground, the current transformer operating a relay when fault current flows to ground.

The application of this fault current relay scheme depends largely upon the arrangement of the grounding busses in which connection tests have been made to determine the proper arrangement and connection of

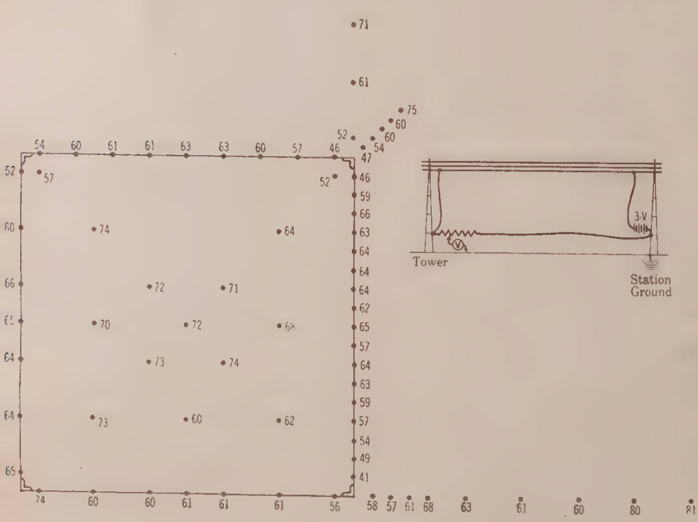

Fig. 7—Potential Gradient Test No. 1

Each number indicates the potential drop from the tower to that point in per cent of the total drop from tower to station ground

Ground resistance at tower = 0.467 ohms

Ground resistance at station = 0.147 ohms

the ground bus to various pieces of equipment. It is expected that further details upon this grounding scheme will be available at a later date and is one of the subjects which should be followed up by the grounding subcommittee next year.

Appendix A

Tests to Determine Potential Gradients in the Vicinity of Transmission Line Towers

Object. To determine if the voltage drop along the surface of the ground in the vicinity of a 120,000-volt

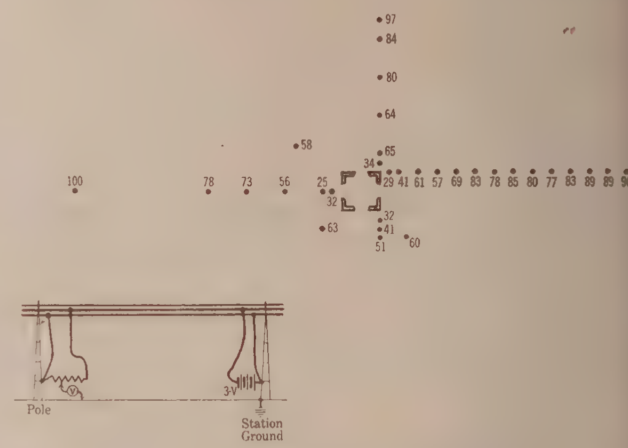

Fig. 8—Potential Gradient Test No. 2

Each number indicates the potential drop from the tower to that point in per cent of the total drop from tower to station ground

Ground resistance at tower = 3.40 ohms

Ground resistance at station = 0.147 ohms

transmission-line tower would be dangerous to life at the instant when one line wire became grounded on the tower in question.

Method. One conductor of the line was grounded at the station, through a battery and the other end of the same conductor was grounded to the tower. A slide-wire rheostat was connected as a potentiometer, from the tower to the station ground, and the slide of the rheostat was at the same time connected through a millivoltmeter to a screw driver, as shown in diagrams 1, 2 and 3.

The screw driver was shoved into the ground at various points in the vicinity of the tower and the slide wire moved until the millivoltmeter read zero. A scale was placed on the rheostat dividing it into 100 parts, the position of the slide at zero reading of the millivoltmeter indicating directly the drop from screw driver to station ground as a per cent of total drop from the tower to the station ground.

Result of Tests:

Test Number	1.	2.	3.
Tower Resistance to Ground	0.467 Ohms	3.4 Ohms	2.6 Ohms
Potential Gredients	See Dia. 1.	See Dia. 2.	See Dia. 3.
Possible ground current in case a conductor becomes dead grounded to tower	5700 amperes	5700 amperes	2375 amperes
Computed voltage to ground	2650 volts	19,350 volts	6,175 volts
Voltage which person leaning against tower could be subjected to.	1,590 volts	12,600 volts	4450 to 6175 volts
Voltage which person standing near tower would be subjected to from foot to foot	200 to 300 volts	3000 volts	1300 volts

Conclusion. These tests show that the potential near a tower is dangerously high at the instant a conductor becomes grounded to the tower.

In this particular case the towers were near a highway and the hazard was considered so great as to warrant the connection of the towers to the station ground with an overhead ground wire.

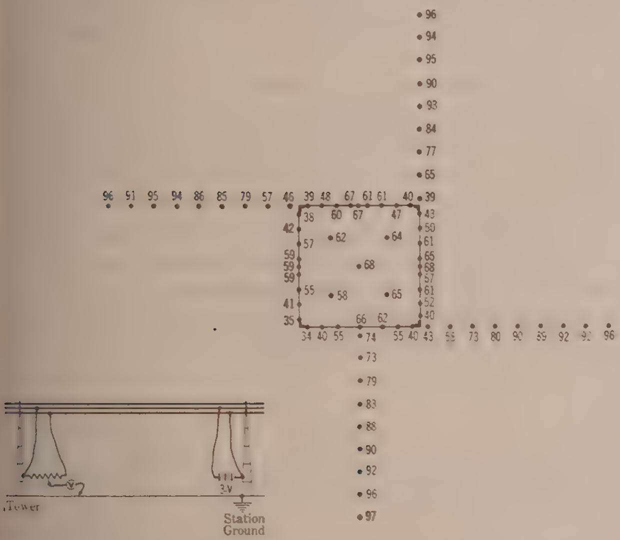

FIG. 9—POTENTIAL GRADIENT TEST NO. 3

Each number indicates the potential drop from the tower to that point in per cent of the total drop from tower to station ground

Ground resistance at tower = 2.6 ohms

Ground resistance at station = 0.147 ohms

Appendix B

GROUND POTENTIAL GRADIENT TEST

The object of this test was to determine the potential gradient in the ground surface surrounding a driven ground pipe when a heavy current flow takes place to ground.

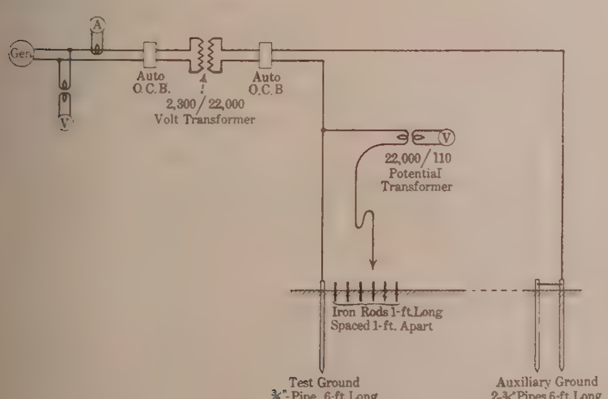

FIG. 10—GROUND POTENTIAL GRADIENT TEST

This test was made with the following equipment available:

1—6250-kv-a., 2300-volt, three-phase, 60-cycle turbine generator.

1—6300-kv-a., 22000/2300-volt transformer bank consisting of 3-2100 kv-a. single-phase units.

1—22000/110-volt potential transformer.

Switching equipment, instruments, insulator platform, etc.

Connections for the test were made as follows:

The test ground pipe was in a sandy soil which was the best location that could be found. Its measured resistance was 280 ohms.

The auxiliary ground, which was 300 feet distant, was in better soil and had a resistance of 53 ohms. By having an auxiliary ground of lower resistance than the test ground, assurance was made that no failure would occur in the circuit outside of the test ground.

The ground current was gradually increased from zero to a value which caused the test ground to steam. At this point the ground current was 30 amperes with an impressed voltage of 10,000 volts across the ground terminals. This value of current was considered the maximum which could be maintained for any great length of time.

With the current held constant at 30 amperes, readings were taken of the voltage drop along the ground surface at one foot intervals in the direction of the current flow between the two grounds. The voltage readings were taken with a 22000/110 volt potential transformer and a 0-150 volt voltmeter; one primary terminal of the potential transformer being connected directly to the test ground and the other terminal was successively touched to one foot iron stakes at various distances away from the test ground. This manipulation was done by an operator standing on an insulated platform and shifting the connections with a switch pole.

Following is a tabulation of the voltage readings taken:

Distance from Test Ground	Voltage Drop	Per cent of Total Voltage Drop at Test Ground
1 ft.	6900 volts	82.0%
2 "	7000 "	83.4%
3 "	7200 "	85.7%
4 "	7400 "	88.0%
5 "	7600 "	90.5%
6 "	7800 "	92.8%

These readings indicate that 82 per cent of the drop occurred within one foot and 92.8 per cent of the drop occurred within six feet of the test ground.

Another set of readings taken three minutes later averaged 700 to 800 volts higher than those shown above, indicating that the ground was baking out, which, was expected, since the ground was steaming in the vicinity of the ground pipe.

Tests made by the Bureau of Standards and reported in Technological Paper No. 108 showed that approximately 90 per cent of the total drop at a ground pipe occurs within a six-foot radius of the pipe. The Bureau of Standards tests, however, showed a much smaller drop within a one-foot radius of the ground pipe. The only explanation for this difference in results is that the

resistivity of the soil around the pipe increased appreciably due to the baking out effect in this test. This emphasizes the importance of making grounds of sufficient current-carrying capacity to meet system requirements.

Lightning Arresters

The work of the Lightning Arrester Subcommittee this year has consisted almost entirely in an effort to list and evaluate the various electrical and mechanical features of lightning arresters.

In order to get an expression of opinion, the form given herewith was submitted as a suggestion in attempting the classification. Members of the subcommittee were requested to give their opinions as to the relative values of the listed features, proportioning each with respect to its importance in their own experience.

Electrical	Weighted Values
1. Spark-over Voltage..............................	
2. Dielectric Spark-Lag..............................	
3. Impedance—Normal Frequency..............................	
4. " —200,000 Cycles..............................	
5. " —1,000,000 Cycles..............................	
6. Discharge Capacity (amperes by time)..............................	
7. Current Passed at Normal Voltage, Normal Frequency, with Gap Short Circuited..............................	
8. Time Required to Interrupt Dynamic Current........	
Mechanical	
9. Condition After Heavy Discharge..............................	
10. Number of Heavy Discharges Arrester will take care of Without Repair..............................	
11. Attention Required in Service:	
(a) None..............................	
(b) Not More Than Once Per Season..............................	
(c) After Every Heavy Discharge..............................	
(d) Once a Day or Oftener..............................	
12. Cost..............................	
13. Depreciation per year..............................	
Total..............................	100 per cent

This was sent out to members and was taken up for discussion at the mid-winter meeting of the main committee. There was apparently quite a diversity of opinion among engineers as to the value and accuracy of such a classification. This diversity of opinion seemed to be, in a large measure, due to varying ideas as to the definition of the duty of a lightning arrester and of the various quantities involved.

The subcommittee was therefore, instructed to make an effort to state definitely the duties of a lightning arrester and to define clearly the quantities which make up the suggested classification. Following this, the subcommittee is to proceed with the classification along the lines suggested.

It is, therefore, possible to report progress only.

The measurement of some of the quantities necessary in making up the classification presents something of a problem. Particularly this is true of the measurement of dielectric spark-lag and the rate of discharge of lightning arresters. It is found that when discussing these quantities, there is a very great difference in the methods used by different experimenters. The different methods in use result in widely different readings of the quantities being sought. It seems that it is necessary to define very precisely, the size of the condenser to be used in measuring the discharge of an arrester; all the characteristics of the circuit to be used in measuring the voltage, and many other similar quantities.

It will undoubtedly be necessary to arrive at some standardization of these measurements before it will be possible to standardize or classify lightning arresters. In order to arrive at a definite method of determining these quantities, the Research Committee has been made acquainted with the problem, and it is hoped that through this cooperation some standard and practicable method of measurement may be obtained.

It is recommended that the succeeding subcommittee continue the work along similar lines.

Relays

Many difficulties have been encountered in the completion of the Relay Handbook. It is now in the hands of the printers and should be available for distribution in June.

This subcommittee is cooperating with the corresponding subcommittee of the Apparatus Committee, N. E. L. A., and plans within the next year to prepare the first supplement to the Relay Handbook. This supplement will be patterned after the Relay Handbook both as to form and size.

Although no new relay developments have been reported to date, several interesting installations have been received. One operating company has made an installation of protective equipment in a generating station, which is rather interesting in a number of respects, particularly in the matter of its completeness. A complete description of this installation appeared in the *Electric Journal* for April, 1924.

This same company has also made use of a variation of the split conductor scheme for the protection of a large frequency changer used for interconnecting 25 and 60-cycle systems. A description of this was given in a paper entitled "Use of Frequency Changers for Interconnection of Power Systems," by H. R. Woodrow, at the Spring Convention in St. Louis, April, 1925.

The problem of protecting generating station auxiliaries was investigated to some extent by this subcommittee, but the findings are not sufficiently definite to report more than progress. It is recommended that the succeeding subcommittee give this matter particular attention, and that the use of the so-called "Voltage Chaser" or automatic throwover switch be investigated. This latter gives some promise of considerable usefulness in assuring a continuous power supply to generation station auxiliaries, and it is felt that the subcom-

mittee can do valuable service in coordinating experience and practise.

Oil-Circuit Breakers

Progress in Standardization. Interrupting rating of oil-circuit breakers was defined by the Protective Devices Committee last year. This definition has now received all of the necessary approvals and is before the Standards Committee for final adoption.

The proposed uniform procedure for testing oil-circuit breakers as prepared by this Committee last year has now been approved by the N. E. L. A. and is, therefore, in line to be used for future tests made by operating companies. Standardizing the methods of making system tests should make possible comparisons between tests on an equivalent basis so that maximum knowledge may be obtained from them.

The new edition of the A. I. E. E. Standards now being compiled will cover oil-circuit breakers much more thoroughly than they are covered by the current edition. The most important new provisions are:

Conditions and Methods of Making Temperature Tests.

Tests of Dielectric Strength and Conditions and Methods of Making Same.

Protection from Voltage Surges.

Attention is called to the following definitions recently adopted by two prominent European technical societies covering certain essentials in connection with oil-circuit breaker performance:

Working Voltage is the maximum potential occuring under any operating conditions at the point where the switch is installed in single and three-phase installations measured between the outer conductors. (Not including over-voltages).

Working Current is the effective value of the maximum current which flows through the switch continuously under any operating conditions (not including short circuit or over-current of short duration.)

Interrupting current is the effective value of the a-c. component which flows through the switch at the moment the contacts are opened during interruption.

Interrupting Voltage is the effective value of the potential which, at the interruption, occurs on the line that remains under voltage immediately upon the dying out of the arc of the interruption in all phases.

The present standard general definition of interrupting rating, paragraph 7090, A. I. E. E. Standards 1922, specifies the rating of current and voltage which the device will interrupt under "Prescribed Conditions." No attempt has been made to date to define prescribed conditions and much further study and experience will be necessary before anything could be done along this line. It appears, however, that sufficient knowledge and experience is available at least to begin studies to define the "Prescribed Conditions." In particular, the great difference in normal recovery voltage across circuit breaker contacts on systems with dead grounded neutrals, as compared with those whose neutral is free or grounded through resistance, makes it very desirable that the "Prescribed Conditions" be determined to the extent of covering this situation. Material economic advantage to many operating companies should result therefrom.

Standardization of interrupting ratings is in active progress at the present time by definite committees, which are now cooperating, to establish standard ratings, so as to reduce the number of circuit breaker designs which must be developed and the number of types of breakers required.

Recommendations. The following recommendations are offered:

a. Definite steps should be taken for a beginning, at least, toward formulating the "Prescribed Conditions" under which an oil circuit breaker is rated. First consideration should be given to the effect of conditions of operation of system neutral on interrupting rating of breaker.

b. Pending the working out of the above problem "Normal Voltage," in the present definition of interrupting duty should be defined so as to permit of no misunderstanding as to its relation to recovery voltage in any given case. Presumably for the present, at least, the breaker should be rated so that the recovery voltage is equal to normal voltage.

c. Definitions equivalent to those for Working Voltage, Working Current, Interrupting Voltage and Interrupting Current given above should be adopted by the A. I. E. E.

ELECTRICAL INTERFERENCE WITH RADIO RECEPTION

In some localities radio reception is seriously disturbed by interference arising from electrical apparatus in the vicinity. Part of the disturbance from electrical devices is practically inevitable, and, like atmospheric disturbances, must be regarded as one of the inherent limitations of radio reception. Some electrical devices when in perfect working order cause disturbances of this kind, while others cause interference because of their faulty operation. The only general remedy for electrical interference is cooperative effort on the part of users of radio, users and owners of the electrical sources of disturbance, and distributers of electrical power, to reduce or eliminate the causes of the trouble. In many cases it is possible to provide filters, shelds, chokes, etc., either at the source of disturbance or at the receiving set, which do much to relieve the difficulties.

A brief outline of the sources of such interference and the methods usually used in mitigation is given in Letter Circular No. 182, copies of which may be obtained upon application to the Bureau of Standards, Washington, D. C.

Changing Transformer Ratio Without Interrupting the Load

BY M. H. BATES[1]
Non-member

Synopsis.—[illegible] *high-voltage transmission* [illegible] *the step-up transformers* [illegible] *out disconnecting the trans-* [illegible] *oad.*

[illegible] *herein described, are the* [illegible] *adjusters and a properly* [illegible] *eaking devices.*

[illegible] *units of any size or to existing banks of transformers by the addition of a regulating auto transformer.*

The range of application has also been extended to include the field of electrolytic reduction and little doubt is held that this very flexible scheme of voltage regulation will fill a long felt need by many generating and distributing systems.

Several installations are already in successful operation and a considerable number are now in the process of construction and operation.

THE expansion of power distribution companies during the past few years has created a demand for an efficient and economical means of regulating the voltage of feeders carrying large blocks of power. This demand is now fully met by the use of a combination apparatus, well past the experimental stage, since several installations are already in successful operation.

Range of Applications

The [illegible] of voltage regulation as accomplished by this device has a great variety of applications. It [illegible]y meets the regulation requirements of any [illegible] transformer bank, and the general scheme is applicable to circuits of any voltage with a wide range of tap regulation, although 20 per cent is perhaps the maximum which it will be called upon to deliver. In the electrolytic field, however, this equipment has been considered for operation over a voltage range of 300 per cent. The total range may be divided into any desired number of steps. No two propositions are [illegible] and but one principle is applied as a solution, [illegible] receiving only special treatment.

The wide flexibility of application of this solution is shown by the following data:

This mechanism has been either furnished or quoted for,

Transformer banks rated as high as	90,000 kv-a.
Circuits up to....................	60,000 volts
Current carrying capacity up to...	1200 ampere
Voltage range through............	300 per cent
Units requiring..................	40 steps

Both single- and three-phase, and any standard connection, can be used therewith. The majority of installations furnished to date are operating on circuits of approximately 13,000 volts and providing from 10 to 20 tap steps, each of approximately 2 per cent of line voltage. The changing of transformer ratio by this device is specially advantageous in units of large sizes due to the relation between cost of transformer versus mechanism.

None of the units in operation required any radical change in design. All parts are standard and thoroughly tried equipment, so combined in a new scheme as to obtain the results desired. A timing mechanism is the only unrecognized part of each unit. This development consists of operating a few shafts and gears in a predetermined sequence. Therefore, interested users of this device should have no hesitancy in the inclusion of it in their systems, believing that it contains untried or unusual devices.

Heretofore, discussion of this subject has been under the caption "Tap Changing Under Load." No doubt this term covers the subject somewhat, yet it does so neither fully nor definitely, as the load is not interrupted nor are the tap bridging contacts carrying any current whatsoever while being shifted from one tap to another.

In general, this scheme of voltage regulation uses a three-phase transformer, or three single-phase units combined with a regulating auto transformer, having on either the high or low voltage side two equal parallel windings. In each winding there are three ratio adjusters, simultaneously operated. Each half winding is capable of carrying full kv-a. while the ratio adjuster of the other half is being changed. This scheme also employs a circuit breaker in each half, and in addition to that, properly timed mechanical gears, etc., to operate each device in the desired sequence.

All transformers with two multiple circuits intended to carry full load are so designed that each circuit can carry full load for one-half the cycle of a ratio change, during which the ratio of the other circuit is being changed, as well as carrying the circulating current between windings during the second that they are in parallel with different ratios; or, in other words, between the time one oil circuit breaker closes and the other one opens.

The operating mechanism as now being manufactured is used intact with minor additions, depending upon operating requirements as to

1. Number of tap steps required
2. Type of circuit breakers desired
3. Source of driving power

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1. Of the General Electric Co. Pittsfield, Mass.

Presented at the Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925.

Operation

The cycle of operation is as follows:

One side of the parallel circuit is opened by means of the circuit-breaking device *A*, Fig. 1, the position of the corresponding ratio adjusters being changed and the winding again connected in circuit. During this portion of switching, circulating current flows between the two multiple circuits approximately one second, due to the difference in ratio of the two windings.

The other side of the multiple circuit is opened by

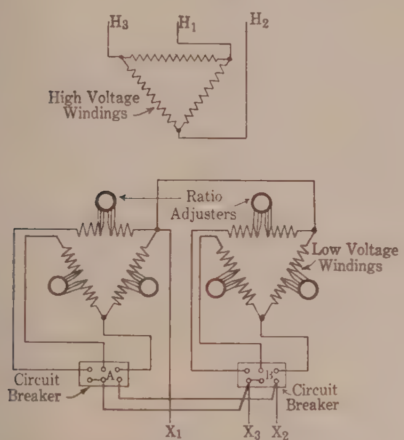


Fig. 1—Wiring Diagram,—Multiple-Circuit Power Transformer

means of the circuit-breaking device *B*, Fig. 1, the corresponding ratio adjusters are brought to the position equalizing the voltages and the circuit again closed, which completes one cycle of operation.

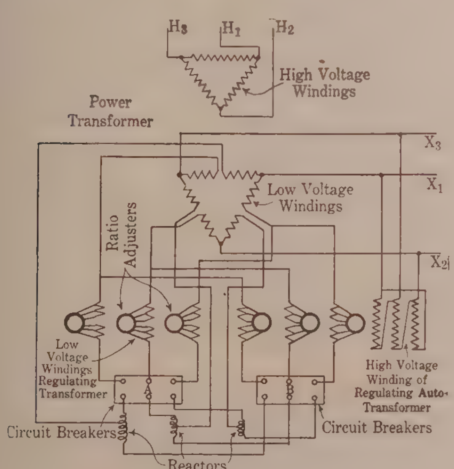


Fig. 2—Wiring Diagram,—Single-Circuit Power Transformer and Auxiliary Multiple-Circuit Regulating Auto Transformer

Several methods of applying this scheme have been proposed as follows:

1. One three-phase power transformer containing two parallel windings, each equipped with three simultaneously operating ratio adjusters having a small time interval between the operation of the two sets. The wiring for this scheme is shown in Fig. 1.

2. Three single-phase transformers and one three-

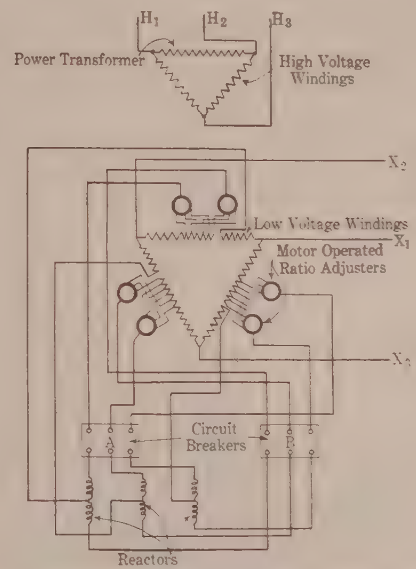


Fig. 3—Wiring Diagram—Single-Circuit Power Transformers

phase regulating auto transformer, similarly equipped with ratio adjusters as shown under Scheme 1. External reactors are necessary during the period of paral-

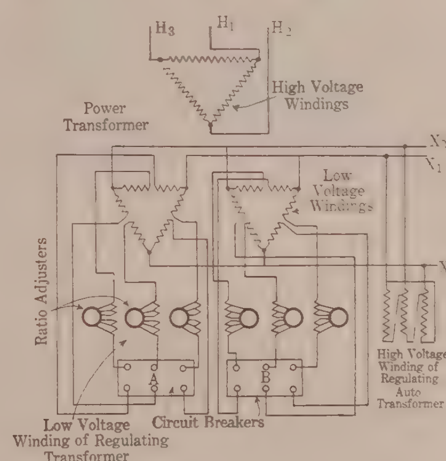


Fig. 4—Wiring Diagram,—Multiple-Circuit Power Transformer and Auxiliary Multiple-Circuit Regulating Auto Transformer

lel operation of the two windings with a difference of one tap in their ratios due to the low reactance of the auto-transformer. These are diagrammatically shown in Fig. 2.

3. Single-circuit, three-phase transformer using the same adjusters but requiring external reactors which are continuously in circuit, illustrated by Fig. 3.

4. Multiple-circuit, three-phase power transformers with the addition of a three-phase regulating auto transformer equipped similarly to Scheme 2, as shown in Fig. 4.

5. Buck and boost connections as shown in Fig. 5 require the same equipment as Scheme 2.

Practically the same cycle of operation takes place in each of the schemes proposed and in general it is as follows: Referring to Fig. 1,

Mechanism. The operating mechanism consists of shafts and an intermittent gear by means of which one revolution of the main shaft operates alternately two auxiliary shafts. Referring to Fig. 7, the auxiliary shafts are alike, together with all of the apparatus controlled by them; and they follow the same sequence of operation. The auxiliary shafts, by means of bevel gears, operate their respective ratio adjusters and, by

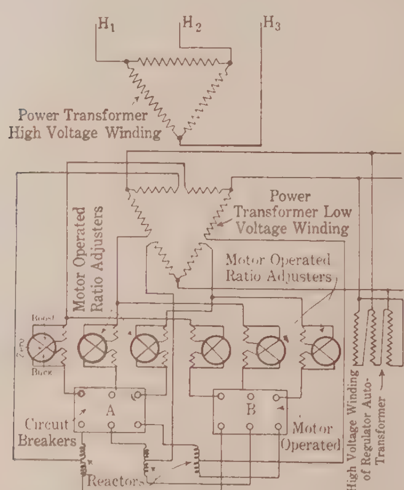


Fig. 5—Wiring Diagram,—Single-Circuit Power Transformer and Auxiliary Multiple-Circuit Buck and Boost Regulating Auto-Transformer

means of a pair of cams, the corresponding circuit breakers, the cams being so designed that the circuit breakers open in advance of the ratio adjuster movement and close the circuit after the ratio adjuster comes to rest. The cams are designed so as to operate positively both opening and closing, although in addition to a toggle joint, a trip mechanism is provided in order that the circuit breaker will open quickly as in ordinary switch operation, but in case the contacts weld the cam will force them open before the ratio adjuster moves. The main shaft may be hand-operated by means of a handwheel or, where remote control is desired, a motor operating mechanism is provided which is in every way identical to feeder voltage regulator equipment.

In order to take care of cases where electrical operation of circuit breakers is preferred, space is provided on the main shaft for the location of a controller by means of which circuit breakers may be controlled electrically in proper sequence with the ratio adjusters.

Each mechanism is totally enclosed in a weatherproof housing, all doors of which are sealed by one lock. This housing is so arranged that the operating motor and its base can be removed as a unit without any dismantling of the mechanism whatsoever from the transformer. All gears, shafting, switch-operating rods, cams, etc., are also enclosed in weatherproof casings and tubes, all of which combine mechanically into a complete casing for all moving parts.

Ratio Adjuster

In the ratio adjusters designed for this service, special attention has been given to the matter of the contact making element so as to make it suitable for large currents and at the same time make it extremely sturdy and reliable. This was done because of the fact that in these equipments the ratio adjusters are apt to be subjected to an extremely large number of operations. The simple and well-known standard finger contacts which have been used for a long time in connection with controllers are employed. These are mounted on a crank shaft and, by means of a simple cam, the position of the contact fingers is positively controlled.

Circuit Breakers

Standard oil circuit breakers are being used to interrupt the current, their rating being determined by the current to be interrupted and the line voltage, except in those cases where the circuit breaker can be placed in the neutral with one side solidly grounded. In this case the voltage rating can be considerably reduced.

It is worth noting that the electric duty on the circuit breakers is very much milder than usual service requirements for which standard oil breakers are designed, on account of the fact that both circuit breakers are never opened simultaneously, their function being merely to transfer the load from one parallel circuit to the other. As previously explained, the voltage which appears across them is equal only to the voltage of one step combined with the impedance drop which exists on the loaded side, and this is only a small fraction of line voltage. Moreover, the breakers will never be called upon to interrupt short circuit except in remote cases of the mechanism operating when short circuit exists.

All of the installations furnished to date are motor-driven and the handwheel is furnished for emergency operation in the case of the loss of the motor supply circuit. Each mechanism is provided with a suitable gear for the installation of a tap position indicating device.

Position Indicator

Two different systems for this feature are available and each has been furnished; first, the Selsyn Indicator and second, an auxiliary tap switch. The former graphically indicates to the operator each step in the

operation of the mechanism by a revolving pointer over a numbered dial while the latter performs practically the same service by means of different colored lamps. The former probably presents the better appearance on the swithcboard and in the case of the latter it requires one wire per step more above four steps than that required for the Selsyn.

Protective Devices

It is highly desirable and therefore recommended that each unit be provided with the following protective scheme which has been used on all equipments to date. Each parallel circuit is provided with current transformers of suitable ratio, differentially connected to act through a timer relay to operate a signal in the switchboard operating room in case one of the oil circuit breakers accidentally opens or fails to close during the cycle of a tap change. It will be noted that two different ratios of current transformers are required in Fig. 1, as they are inserted between windings containing adjusters and the circuit breakers. This is necessary since current transformers are within the leg of each of two phases while the third is in the line lead from a delta.

Further protection must be provided where solenoid or motor-operated circuit breakers are used, to insure stopping the mechanism motor if direct current is not available for operation of the breakers, and also to protect the adjuster from acting as a circuit breaker or closing device if either breaker fails to open or close. This protection is afforded by means of auxiliary switches mounted on the circuit breakers and electrically interconnected with the controller of the operating mechanism, and a magnetic lock on the main shaft of the latter. Each mechanism is provided with cutout and fuse box for the operating motor circuit, as it is necessary to open the motor circuit if it is alive, during a period of hand operation for testing or adjusting purposes. This is necessary due to a novel feature of the mechanism, in mechanically holding the relay switch closed after it has been closed by electromagnets and held thus throughout a tap-changing cycle. Therefore, it is not necessary to keep the control switch closed any longer than to merely start the mechanism, as it will automatically come to rest at the completion of one cycle.

There is also provided a tap indicating dial for hand operation.

Installations

Regarding the installation of this equipment, little additional work has been found necessary in the field over and above that required for ordinary transformer, installation, as the mechanism, with its housing, is shipped completely assembled and only needs lining up on its own base and connecting through its connecting rods and casing to the main transformer tank. Electric cables for the equipment are also furnished complete to a terminal block in the mechanism and nothing remains to be done other than wire between this block and the switchboard. In this, the protective wiring is not included.

It has been found possible to ship all the power transformers, equipped for this type of ratio changing, completely filled with oil, so that even though this feature is included in large power units it has not necessitated an increase in physical size, such as to render it necessary to dry out the windings at the customers' plants.

An example of the usefulness of these devices is the installation at Chester, Pennsylvania, where a power plant is supplying, from the same bus, a local load and a larger load to Philadelphia, twenty miles away. By using four 20,000-kv-a. transformers provided with this

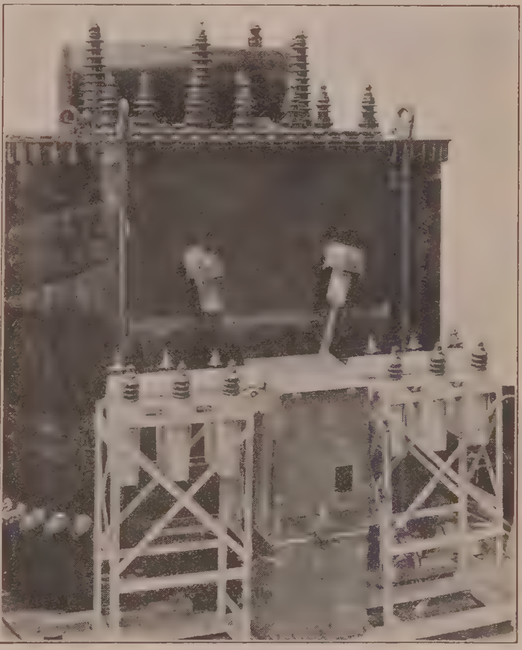


Fig. 6—Outdoor Transformer from Low Voltage Side

device, the voltage on the Philadelphia load is controlled independent of the local load conditions. The regulating equipment is a part of the 13,000-volt circuit, and seven voltage steps through a total voltage range of 12 per cent is obtainable. The equipment is outdoors and the circuit breakers are cam-operated. Four independent push-pull button controls, one for each unit, are located in the switchboard room, about one quarter of a mile away. Fig. 6 illustrates the completely assembled transformer mechanism and oil circuit breakers.

The switchboard panel for each unit is equipped with a Selsyn indicator which, actuated by a Geneva gear in the mechanism, indicates to the operator the instant the mechanisn is in motion and again when it has come to rest. An additional device for each unit furnished consists of a Geneva gear operated controller on the

main shaft of the mechanism, a compensator or auto transformer in the housing, and a voltmeter on the switchboard. The purpose of this latter equipment is to indicate, in the operating room, the high line voltage at a predetermined point on the transmission line.

It was found necessary to use this equipment for changing ratio from two to six times a day.

A few items of interest concerning this installation are as follows:

Weight of transformer interior......	56,800 lb.
" " oil....................	46,200 "
" " mechanism............	1,600 "
Total weight......................	130,000 "

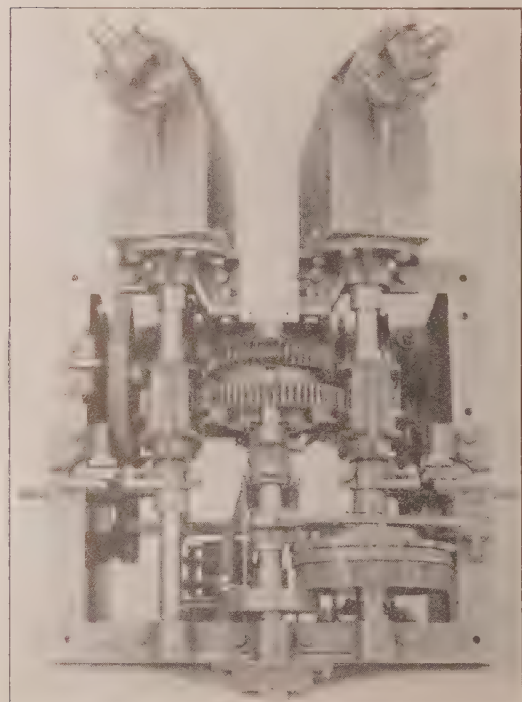


Fig. 7—Showing Mechanism for Transformer Step Voltage Regulator—Top View

The entire equipment was shipped on a deep-well car, the tank containing all the oil except that for the conservator, which accompanied the unit in drums.

A very similar installation, with the exception that the breakers used are indoor solenoid-operated type, consists of two 20,000-kv-a. units each having nine voltage steps. These transformers are about to be placed in service at Buffalo, N. Y. The mechanism is designed to give a complete tap change in twenty seconds with the use of a controller as the means for timing. A longer period is required to properly carry out the operation of this type of breaker than is necessary with a mechanically operated one.

In an installation soon to be in operation at Peoria, Ill., a 30,000-kv-a. transformer bank is provided with a 16 per cent voltage range in seven steps by means of an auxiliary regulating auto-transformer connected into the low voltage or 15,000-volt side of the power units. This unit also requires twenty seconds for a complete tap change for the same reason as in the preceding installation, although motor operated breakers are supplied.

Another installation using Scheme 5, previously listed, will shortly be in operation to give a 10 per cent boost and 10 per cent buck in a 66,000-volt line carrying 36,000-kv-a. This installation will have nine equal steps either side of neutral.

The foregoing shows the variety of uses to which this device has been applied handling large blocks of power. Another field has recently been entered, in which this scheme of voltage control may play an important part, and this is electrolytic reduction. Work is well under way on transformers about 3000 kv-a. in size, with adjusters in the two parallel high voltages windings, to give a low tension voltage range of from 60 to 130 volts.

It is not an accident that these devices are being furnished in connection with the voltage control of very large blocks of power. The fact that the regulating equipment can be made part of a power transformer without greatly increasing the kv-a. rating results in economy in first cost and high operating efficiency, providing the transformer rating is sufficiently large. Furthermore, changes in the load where the kv-a. is large, are much more gradual and occur less often than when smaller amounts of energy are to be cared for. Therefore, regulating apparatus capable of operating very quickly and very often, as is the case with induction regulators, is not so essential.

For the reasons given, greater economy, greater efficiency are available and the general performance of the device makes it particularly desirable where voltage control is required in connection with very large amounts of power.

HYDROELECTRIC POWER-PLANT IN BRITISH COLUMBIA

One of the largest hydroelectric power plants on the North American continent is about to be constructed approximately 135 miles north of the city of Vancouver at Seton Lake, the Department of Commerce is informed by Consul E. L. Harris, Vancouver. Within the next five years it is planned to spend $13,000,000 in the development of the first unit. Sixty thousand horse power will be available from this new installation. Additional units may be installed later.

The exhaust gases of the Diesel engines will be used upon four new German ships to generate electricity which will be utilized for lighting and cooking purposes. The hot exhaust of these engines will be passed through specially designed boilers and the steam so generated will, in turn, be used to drive electric dynamos.

Engineering Research—An Essential Factor in Engineering Education

BY C. EDWARD MAGNUSSON[1]

Fellow, A. I. E. E.

IT may seem trite to assert the interdependence of engineering research and engineering education, and no doubt most workers in the vinyard would consider the title of this paper as axiomatic,—the statement of a self-evident fact. *In theory* the great majority of the members of our engineering faculties, as well as practising engineers, who have given time and thought to the training of young men for the engineering profession, readily subscribe to statements emphasizing the importance of research as a factor in engineering education; but *in practise*—well, "the spirit is willing but the flesh is weak."

In the majority of our engineering colleges and technical schools very little if any research is in progress, and even in our leading institutions comparatively few members of the teaching staffs are actively engaged in worth-while investigations. As yet the research spirit is an attribute of individual members of the faculties and not of our engineering colleges as institutions. Professors who have gained recognition as investigators are looked upon as ornaments, and not as the bone and marrow of the university. Research remains a side issue, something very desirable and highly creditable to our technologic institutions, but not to be taken seriously as an essential factor in the training of engineering students.

The rapidly increasing importance of engineering research in the industries stands in striking contrast to the apathetic condition that exists in many of our educational institutions. In large manufacturing concerns the research departments have gained in recent years prestige and influence far beyond the fondest dreams of the pioneering investigators of thirty or forty years ago. The development of new ideas is by now an integral, and, in many cases, a vital part of industrial organizations. Research engineers are continually transforming new ideas into effective weapons of offense and defense in present day industrial warfare. The research departments provide the means for gaining new markets, and form the bulwarks of defense against competition in established fields. That industrial research will continue to expand is certain, as the work rests on a sound economic basis. Properly conducted research not only pays well—in fact brings large returns on the investment—but is a basic necessity, in order to enable industrial organizations to live and prosper.

While, in the main, the expansion of research in the industries has had a salutary effect on our engineering colleges, still it has developed conditions adverse to the effective training of engineering students. Industrial research has emphasized the importance of giving students clear concepts of well established fundamental principles and created a new and highly attractive professional field, thus providing the studious, scientifically inclined, engineering student with a better appreciation of fundamental physical laws and a definite goal for his ambition—to become a research engineer.

Of adverse factors two are of special significance:

1. The type of mind required for becoming a successful research engineer is essentially the same as for gaining prominence as a professor in some field of engineering. As industrial concerns are able to pay larger salaries than educational institutions, and what is often of greater importance, can provide better facilities for carrying on investigations, the teaching staffs are being robbed of their best men, and, to a large extent, have been cut off from the supply of desirable recruits. This factor affects not merely the faculties of engineering departments but likewise those of physics and chemistry. Unless this movement can be checked and emoluments of professors be made as good or better than those given to research engineers, the results will soon prove disastrous to technologic training. For, in order to have a first class college of engineering, there must be first class men on the faculty.

2. Even under present conditions, the amount of research accomplished by industrial concerns is overwhelmingly greater than what is done in the universities and professional schools. With industrial research staffs having several thousand members—as, for example, the recently organized Bell Telephone Laboratories—and with adequate facilities at their disposal, is there any wonder that the research output of a college faculty, with its members giving practically all their time and effort to teaching, should be very small in comparison? The contents of our scientific and technical journals and the proceedings and transactions of our scientific and technical societies give evidence of the increasing preponderance of papers from industrial research departments, with a corresponding relative decrease in contributions from educational institutions. To those who are familiar with existing conditions for conducting research in our colleges of engineering and institutes of technology, as compared with the facilities provided by research departments of many industrial concerns, the wonder is not how little, but how surprisingly much the professors actually accomplish.

Still the distressing fact remains that the relative

1. Dean, College of Engineering, Director, Engineering Experiment Station, University of Washington.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 17-19, 1925.

importance of our institutions of learning as centers of research is rapidly decreasing, a situation that should be given serious consideration, not only by faculty members of our engineering colleges and technical schools, but likewise by all progressive engineers and captains of industry. It is, by now, quite generally recognized that during his four years in college, the main purpose of the prospective engineer is to acquire a mastery of engineering fundamentals and a working knowledge of mathematics and English, while comparatively little importance is attached to the gathering of detailed information on current practise. (In paranthesis it may be noted that while engineers and educators are generally agreed that the major part of the student's time and effort should be given to engineering fundamentals, there are apparently widely divergent views as to what the term implies. For the purpose of this paper let it be assumed that by *engineering fundamentals* is understood the *basic physical laws* with and under which the practising engineer works, lives and has his being.) The student in college should gain a deep and full realization of the far reaching importance of the principle of the conservation of energy, Newton's, Joules', Ohm's and Kirchoff's laws, and similar established basic physical relations, and *acquire the ability to apply them correctly to quantitative engineering problems.*

In order to give the student a clear insight into the basic laws of engineering and their application to quantitative problems, with that perspective of coming events so tersely expressed by Mr. B. G. Lamme: "*it should be remembered that much of what these young men will work with has not yet been discovered*" and requires teachers who are continuously applying basic principles in their own search for new truths. The title "research professor," which, in the last few years, has made its appearance in several university catalogues and bulletins, indicates an unfortunate tendency. It gives official recognition to a separation of the teachers from the investigators—and thereby erects a new barrier between the students and the progressive thinkers on the teaching staffs. It would be better both for the students and institutions, if successful research could be made a requirement for all members of the faculty, and that in rating our engineering colleges and technical schools, more emphasis could be placed on the quality and number of engineering bulletins and scientific papers published than on the number of students or available laboratory equipment and size of buildings. There can be no question that much more research must be done in our engineering colleges than obtains at present. Attempting to solve new problems is the best means for developing initiative and the ability to think.

If it be admitted that research surroundings are essential to the proper training of engineering students, and that present conditions in most engineering and technical schools make worthwhile investigations well nigh impossible, it is evident that the question of improving existing conditions must be given serious consideration.

Of course most of the difficulties that beset our engineering colleges would be eliminated if adequate funds were available for research facilities and pay for staff members comparable to those provided by industrial organizations; but there is little hope for general relief in this direction as the number of students seeking training is, in most institutions, increasing at a greater rate than the material wherewithal. As a more likely method for bringing engineering students in touch with worthwhile investigations, the author would stress the importance of a closer and more extensive cooperation between the research divisions of industrial organizations and educational institutions. The following suggestions are submitted:

1. Industrial organizations should establish numerous *research fellowships in engineering colleges,* not as gratuities but as necessary investments against their own future need of properly trained additions to their staffs.

2. *Cooperative work between research departments of industrial organizations and educational institutions* should be greatly increased.

3. Some form of *bonus system* should be established by which engineering colleges would receive financial returns from industrial organizations for having discovered and trained exceptionally successful engineers.

4. Let educational institutions take out *patents on new ideas of commercial value* originated by faculty members; that is, expand and make effective the plan recently adopted by Columbia University.

5. Establish research foundations as integral parts of engineering colleges.

6. Let a larger share of the normal income of educational institutions be expended on investigational work. This would be in accord with the policy adopted by industrial organizations. Twenty or thirty years ago the budgets for research were insignificant in most of our industrial organizations, while today the research divisions in several manufacturing and operating companies expend millions of dollars annually.

7. There should be instituted an *exchange of engineers* between engineering faculties and engineering staffs of manufacturing companies and other industrial organizations, the plan might be somewhat similar to the *exchange of professors* between European and American universities. If a man for man exchange could not be effected, let the manufacturing companies donate the services (Sabbatical year) of some of their engineers, who would devote all of their time in selected engineering schools during a full academic year.

To properly train engineers is an expensive process. To obtain satisfactory results our engineering colleges must be provided with much *greater financial support* in the future than has been the case in the past. If the service rendered by our engineering colleges is of value

to industrial development, let organized industries assist in providing adequate means so that the work may be well done.

If the basic necessity for research on a scale larger than hitherto exercised in our engineering colleges and technical schools be fully understood and appreciated, means and methods for improving existing conditions will no doubt be forthcoming.

Discussion at Swampscott Meeting

STUDIES OF TIME LAG OF NEEDLE GAPS[1]

(McEachron and Wade)

Swampscott, Mass., May 9, 1925

C. H. Dagnall: I should like to ask Mr. McEachron what method he used to have the specified amount of gas—inert gas—inside of a tube to concentrate a stream of electrons into a point. It has been found that when a definite amount of inert gas is present in the cathode-ray tube, due to ionization of this gas, the electrons flowing are concentrated into a very fine stream, instead of spreading out due to repulsion between the electrons and the stream itself. I should like to know what method Mr. McEachron used to produce this definite amount of gas.

H. B. Smith: I think this paper of Mr. McEachron deserves discussion, and, in my own case, appreciative discussion, because in 1914 we attempted at Worcester to carry out a little of the fundamental research on dielectrics which Professor Adams pointed out the other day as important, as a basis for cable design as well as other things. We wanted to see what could be determined with regard to the analysis of dielectric phenomena occurring when approaching the point of breakdown of the dielectric. We wanted to get polar oscillograms of half waves of current and voltage on a sample of dielectric just previous to the point of breakdown, in order that we might analyze the phenomena going on in the dielectric under that condition.

Now, our first attempt, beginning about 1914, although recognizing the inherent difficulties of any instrument involving inertia, was with the application of the Einthoven galvanometer, which minimizes inertia of parts for the current wave. An electrostatic instrument with a very fine metal filament deflected in an electrostatic field was used to get the voltage wave simultaneously, with a suitable photographic optical system, shutter, etc., so that we might obtain a half wave of both current and e. m. f. on a polar diagram of sixty cycles.

That was not the high speed with which Mr. McEachron has worked, but still it is fairly high, and we obtained very good polar diagrams under those conditions. But the diagrams were of such a character that the more we studied them, the more we were afraid of the inertia effect.

So the next step naturally taken up was the application of the cathode ray, and in that case, we made use of the Western Electric Company's development of the cathode-ray tube, and ran into just the difficulty mentioned by Mr. McEachron with regard to getting a satisfactory photographic impression at that speed. We couldn't do it. We had just about reached that point when we learned of the Dufour instrument and attempted to make use of that. This was around 1917, and the war conditions made it impossible to continue the work.

However, experience with this instrument shows that we can secure such records as are needed for half periods on samples of dielectric, under the unstable conditions approaching breakdown. It offers opportunity for this in a most promising fashion.

W. L. Smith: I was wondering how far it is possible to carry this speed before one runs into the difficulty of the change of inertia of the electron with its speed, limiting the speed of the phenomenon to be measured.

1. Presented at Swampscott Regional Meeting, Swampscott, May 7-9, 1925.

Saratoga Springs, N. Y., June 26, 1925.

E. E. F. Creighton: In the early years of lightning arresters and protective devices' development I spent many hours with Dr. Steinmetz speculating on what might be taking place in the earlier parts of our artificial lightning discharges. We could estimate, in a way, what extremely high frequencies might be brought into existence—superposed on our lightning frequencies which were, as a matter of fact, carried as high as 5,000,000 cycles per second—but there was no assurance that these superposed higher frequencies actually existed to any appreciable degree. The mathematical calculations of the resistance of the "skin effect," for example, indicated that such high frequencies would be damped out immediately. These puzzles of more than twenty years' standing have been carried in our minds. Therefore, to me, personally, it is a most peculiar pleasure to look on these oscillograms of records of millions of cycles per second and see the complete solution of our speculative problem.

I wish to make one correction as to the authors' credit given to Mr. Duddell in the matter of the early work on the oscillographs. There are three men who stand preeminent in the development of the oscillograph—Blondell in France, Duddell in England, and our good friend, Louis Robinson, in America.

André Blondell is, without doubt, the father of the oscillograph. In 1898 I passed through London on my way to Paris and spent a day with Mr. Duddell. He was just getting his oscillographic work under way at that time. Upon arrival in Paris I found that M. Blondell had had his oscillographs in use for a long time. He had both the magnetic-needle type and the bifilar type which is in such universal use today. The practical oscillographic apparatus which all of us know and find so convenient to use is entirely the work, one might say, of Mr. Robinson.

L. R. Golladay: I was interested in the author's investigation of the impulse circuit resistance to give most nearly a vertical wave front. It seems to me that a moderate amount of overshoot with a steeper wave front might not be objectionable. If the frequency of oscillation were high enough, the effects on the time lag of the alternate half-waves would, at least approximately, cancel out.

The authors conclude that the percentage of over voltage required to keep the lag at two microseconds or less, decreases as the gap spacing increases. This conclusion must be based on data not included in the paper. It is to be inferred from Pedersen's work that the percentage of over voltage to keep the time lag constant with increasing gap length would increase.

I have referred above to the work of P. O. Pedersen who has published two important papers on spark lag in the *Annalen der Physik*. His method makes use of the velocity of spreading of Litchtenberg's figures, and of the velocity of propagation in conductors, to measure time lags of the order of 10^{-8} seconds. The present paper indicates that very careful work is required to obtain consistent results in measuring times as short as those measured by Pedersen. A few of the latter's conclusions are as follows:

(a) For constant gap length, the time lag decreases as the excess voltage increases. A similar conclusion is reached in the present paper.

(b) For constant surge voltage, the time lag decreases to zero as the gap length is shortened.

(c) Effects of electrode shape.

1. For equal gap lengths, needles and points are faster than sphere-gaps.

2. For equal time lags, a needle gap is about one-third longer than a sphere-gap.

3. With a gap of 3 mm., and about 100 per cent excess voltage, the time lag of a 10 mm., diameter sphere-gap was found to be 10.5×10^{-8} sec., and of a needle gap, 5.6×10^{-8} sec., at the same voltage.

4. The time lag of a gap is determined almost entirely by the shape of the anode, and the cathode has practically no effect. This accounts for the results obtained with a gap between a point and a plane in the present paper.

(d) A minimum time lag is obtained with clean electrodes, which may be multiplied by five or more by contamination of the electrodes surface. The effect of a spark is to increase the time lag for subsequent sparks due to corrosion of the electrode surface.

Time lag depends more upon the ratio of impressed voltage to breakdown voltage, than upon gap length, although there is a slow increase with increasing gap length.

The above results were obtained with relatively short gap lengths—usually of a few millimeters. It is interesting to note that Pedersen found that the time lag is more affected by the electrode surface than by the electrode shape.

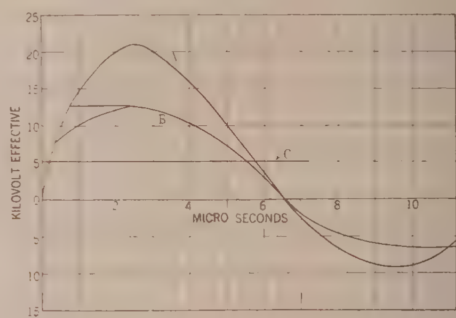
In the course of lightning-arrester development work, the writer had occasion to develope a means for measuring time lag of insulator flashover, breakdown of spark-gap, and discharge of lightning arresters. Satisfactory answers to these problems were obtained with a "timing" circuit consisting of a condenser and resistance connected in series and shunted across the apparatus to be timed. The peak voltage of the condenser is measured by a small sphere-gap in the case of long time lags, or by a klydonograph in the case of short time lags. With the assumption that the voltage impressed on the timing circuit has a rectangular wave shape, the time is given by the formula $t = R\,C \log_\epsilon \dfrac{E}{E - e}$, where R and C are the constants of the timing circuit, E the surge voltage. and e the condenser voltage. With this method we have obtained a figure of 2.7 microseconds for the time lag of a 25-kv., pin-type insulator with 150 kv. impressed. The time lag of a 25-cm., sphere-gap set at 8.5 mm., was 0.24 microseconds with 36 kv. While the sphere-gap is fast, it is not instantaneous. It has a measurable time lag.

As a matter of interest some tests were made under one of the conditions of the present paper, a 12-mm. needle gap at 22 kv. A 0.1-microfarad condenser supplied the surge through a 675-ohm resistor. The results obtained were: Minimum time lag, 0.83; average 3.3; and maximum 13.8 microseconds. These results are of the same order but somewhat lower than those of the paper. I believe that the discrepancy is due to differences in tests conditions. The results with the needle gap were quite erratic compared to those obtained with sphere-gaps. The major inconsistencies are probably due to microscopic differences in the needles. The smaller differences are encountered when testing with sphere-gaps and are probably due to minor changes in test conditions.

E. E. Burger: One of the most important uses of the cathode-ray oscillograph at the present time is to study the operation of lightning arresters. Heretofore, we have had to rely chiefly upon sphere-gaps for measurements but since only maximum values could be measured and the time element was not considered, questions of uncertainty always accompanied the measurements. By applying this oscillograph to lightning-arrester test circuits a new field of information has been opened for study.

In the study of lightning arresters, there are two important points that we wish to consider from the protection standpoint: First, how much above the insulation test voltage do the arresters allow the voltage of the transient to go, and second, what is the duration of this over voltage. Most insulation has a test voltage of approximately two times normal for one minute. Studies of the mechanism of insulation breakdown seem to indicate that insulation failure depends upon an overvoltage-time characteristic.

The accompanying curves show two cathode-ray oscillograms transcribed into rectangular coordinates. The ordinates represent the value of voltage impressed across apparatus insulation, and the abscissas give the duration. Curve A shows a transient's characteristics without the lightning arrester, and Curve B shows the change in the transient caused by the operation of the arrester. Line C would represent the A. I. E. E. value of test voltage. The area under Curve B and above line C represents the realm in which insulaton may become damaged.



Oscillograms Showing Rise of Voltage (A) Without and (B) With Lightning Arrester.

Now the question is; what kinds and shapes of transients shall we apply to arresters? In the laboratory it is possible to produce transients of almost any wave front, voltage or duration, but we do not know how these transients compare with what we actually get in practise. This is one of the most important points we should know, and possibly through the use of this oscillograph or other instruments, we may be able to determine some of these factors.

L. T. Robinson: In connection with this instrument, it is interesting to recall that as early as 1903 a device making use of the cathode-ray tube for obtaining photographic records of electrical wave forms was developed and described by our past-president Harris J. Ryan.[2]

K. B. McEachron: No direct determination of the correct amount of residual gas is made. The condition of the vacuum for proper focusing is determined by observing the appearance of the cathode stream. To be able to judge properly the size of the spot in this manner requires some experience on the part of the operator. The gage shows a pressure of from 2 to 6 microns, but the gage indication is not depended upon for determining the proper vacuum condition.

The question of limitation of the oscillograph raised by Professor W. L. Smith is an interesting question. The electron speed corresponding to the voltage used is about one-third that of light. At this speed the limitation does not depend on the velocity of the electrons but rather on means of drawing out the wave along a time axis.

We have used oscillator frequencies as high as 1,000,000 cycles, detecting frequencies on the unknown transient of more than 100,000,000 cycles. Still higher frequencies may be studied but the sweeping rate becomes so high that it is difficult to time the phenomena properly. For most work it is doubtful if much is to be gained by going to frequencies higher than this.

Concerning the effect of spacing on the percentage of over voltage required to keep the lag to less than two microseconds. mentioned by Mr. Golladay, the detailed data were not included in the paper, but the data for three different spacings were given

2. The Cathode-Ray Alternating-Wave Indicator, by Harris J. Ryan A. I. E. E. Transactions, Vol. XXII, 1903, page 539.

in the text near the end of the paper. The results in the table are for lags of two microseconds or longer.

The results obtained by Pedersen are of interest, but as Mr. Golladay states, they were obtained on relatively short-gap lengths with which electrode conditions are of greater importance than with larger gaps.

The time lags on the insulation and sphere-gap as given by Mr. Golladay are of note, but the results will depend considerably on the wave shape applied. Considerable error may be introduced when using this method by assuming a perpendicular wave form for calculation purposes.

Mr. Golladay used a much smaller sphere-gap setting than is standard for 25 cm. spheres which is probably the reason for the rather long time lag given. Peek[3] has shown that considerable lag may be expected with gaps much smaller than $0.3\sqrt{R}$, where R is the radius of the sphere in centimeters.

Discussion at Spring Convention

MISSISSIPPI RIVER CROSSING OF CRYSTAL CITY TRANSMISSION LINE[1]

(Eales and Ettlinger)

St. Louis, Mo., April 14, 1925

J. S. Martin (communicated after adjournment): I have been especially interested in the authors' methods of calculation of the sags required in the wire, as this is a subject of which I have made considerable study. In the proceedings of the Engineering Society of Western Pennsylvania for November 1922, I published a tabular method of calculating sag including a set of tables giving the functions of the catenary in the same manner that the ordinary trigonometrical tables give the functions of the circle. By means of these tables the sag required for any span and any wire can be quickly and accurately determined when the span is level. For the calculation of spans on the slope, the writer has resorted to an approximate method which gives results as close as the work of sagging can be done in the field and in nearly all cases the slight error is on the safe side.

The accurate calculation of the sag of wire in a span where

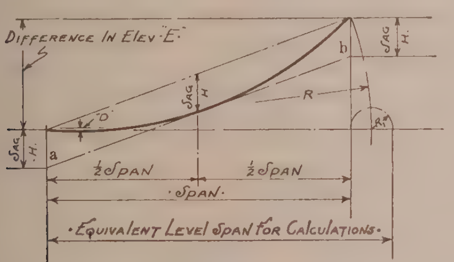


Fig. 1

the supports are not on the same level is a long and tedious process for an expert mathematician even when assisted by these tables, so that for general use in transmission-line work the accurate method is impractical. The computations presented by Messrs. Eales and Ettlinger have afforded the writer an opportunity to compare results with his method.

The method used by the writer for general calculation of sag in sloping spans is to take the difference between the level measurement of span between the points of support, and the actual measurement between these points of support. This difference equals R_1 in the accompanying diagram. Then add this difference to the actual distance between points of support, and use this value as an equivalent level span.

A marking point is then placed on each tower at a distance from the point of support equal to the sag H, of the equivalent level span. See a and b in the diagram. A line of sight $a - b$ is taken between these two marking points, this line of sight being parallel to a line joining the points of support. The wire is then sagged till it strikes this line of sight.

If the wire would hang in a parabola, a similar method could be used, using the level measurement between the points of support as the length of span and the results would be accurate, but since we assume that the wire is hanging in a catenary, there must be a correction, and the method mentioned above is the one used by the writer to obtain this correction. No mathematical demonstration can be given by the writer for this method, except that it is the result of a long series of test problems.

The calculations for the sag of the wire in the span under consideration can be obtained by the tabular method in an hour or less of work and the computation can be entrusted to an apprentice or office boy. With the method presented by the authors of the paper under consideration, the calculations will take a long time and must be made by an expert mathematician.

The writer has compared the results obtained by the two methods and it was found that they differ in giving the elevation of the low point of the wire by about 2.2 ft. In order to check the accuracy of these results the writer calculated the exact location of the low point of the wire at zero temperature. It was found that while for zero temperature there is a difference of 2.19 ft. between the results obtained by the two methods, the exact method gives a result between the two, giving an elevation of 0.73 ft. above the elevation given by the method presented in the paper and 1.46 ft. below the elevation given by the writer's method. This would show that the error of the writer's method is about 0.45 per cent while that of the method given in the paper is 0.30 per cent. This percentage is based on the maximum tension in the wire as strung according to the two methods. This happens to be one of the few cases where the writer's approximate method for sloping spans would give a stress slightly in excess of the theoretical stress desired, but the results are well within the limits of the probable errors in field work and in the assumptions with regard to the quality and characteristics of the wire used, so that this error is negligible.

Where it is necessary to know the elevation of the low point of the wire for determining clearances, the writer has found the following parabolic formula sufficiently accurate for practical purposes.

Let, H = sag as determined for the equivalent level span as previously explained

E = difference in elevation of the points of support

D = deflection of low point of wire below lower support

Then,

$$D = (1/H)\,(H - E/4)^2$$

In our office, a large part of our routine calculations for sags in wires are entrusted to an office boy to do in his spare moments. The tabular method is so well adapted for the use of a calculating machine, such as the Marchant or Monroe, that it is no trouble at all for any person who is ordinarily careful to determine quickly the proper sag in the wire even for important spans.

E. Ettlinger: The solution of the specific engineering problem of this river crossing, due to the nature of the profile, produced two adjacent long spans. The desire to avoid dead-end construction, influenced the use of insulating supports in suspension on the intermediate tower. Initially, consideration was given to a roller-cradle type of support which would allow the cable to roll from one side to the other with changes of temperature and loading. Numerous objections were found to this type of support, the most serious of which was the danger incident to the dropping off of ice in one span while the ice

1. A. I. E. E. Journal, Vol. XLIV, Oct. 1925, p. 1106.

3. A. I. E. E. Transactions, Vol. XXXIV, 1915, page 1897.

remained on the adjacent span, resulting in the decision to clamp the cable definitely.

The clamping of the cable at the intermediate tower and supporting it by suspension assembly of insulators introduced the problem of the stress in this support due to temperature and loading variations. Calculations indicated that the suspension assembly would not vary from the vertical by more than approximately 5 deg. Although the suspension assemblies were designed for one-half the ultimate strength of the dead-end assemblies, the actual component of force in them would not reach an excessive value.

The authors are aware of the fact that there are numerous noteworthy tabular and chart methods of calculating spans with supports at equal elevation. Also that various approximate methods are in use by which spans with supports at unequal elevations may be calculated.

The importance of the problem involved in crossing the largest and most important navigable river in this country, it is believed, warranted the development of a direct method of calculations for spans with supports at unequal elevations. The expense and time required to make these calculations are really insignificant when it is realized that the design and construction of a crossing of the Mississippi River with the rigid requirements of clearance as specified by the War Department involves considerable responsibility.

Problems of this magnitude arise but infrequently and are hardly to be classified as a matter of routine calculation. The method was developed for the specific purpose of assurance of span performance and as a check on less accurate and empirical methods. The method of calculation illustrated in the paper should not consume more than three or four hours to complete after one is familiar with the procedure.

Discussion at Annual Convention

THE LOADED SUBMARINE TELEGRAPH CABLE[1]

(Buckley)

Saratoga Springs, N. Y., June 26, 1925

W. C. Peterman: This paper treats of a phase of communication that apparently has not kept pace with the advances in other methods of communication. Numerous inquiries have been directed in recent years about the cause of this apparent lack of progress in the field of cable telegraphy. As a matter of fact, a very considerable progress has been made in the past 10 or 15 years. The improvements in this period, principally in the terminal apparatus, repeating apparatus and operating methods, resulted in a substantial increase of speed and a reduction of operating cost. There were, among others, the introduction of a successful relay to automatically connect two cable sections, the development of an amplifier suitable for cable conditions, and the improvement in the design and use of artificial cables for duplexing.

During the past few years there has also been developed by the Western Union engineers, a system of repeating-cable signals which completely regenerates them as to shape and strength so that on leaving the repeating station they are as perfect as when originally sent. This system permits of the insertion of a number of repeaters in a circuit where previously one had been the limit. By this method, automatic, through operation direct between New York and London was for the first time successfully accomplished. There has also been developed a special printing telegraph system which permits of a higher operating speed in letters per minute than can be obtained with the usual cable code which had heretofore been considered the fastest system for ocean cables. This printing method has proved highly successful on a through circuit from New York to London with duplex operation.

When the possibilities of this new type of cable, as outlined by Dr. Buckley, were presented to us, we were immediately interested. Our engineers went into the subject as presented to them, and came into entire agreement on all points. From then on our engineers checked over the designs and plans at every stage to satisfy themselves as to their correctness, for a submarine cable is such a large, long-time investment that every precaution must be taken to insure nothing having been overlooked. As an additional precaution a trial 120-mi. length of loaded cable was manufactured and laid in deep water off Bermuda. The results of tests made on this cable were in accordance with predictions from the previous laboratory tests and theoretical studies made by Dr. Buckley. The Western Union was satisfied with the results and proceeded to lay the 2300-mi. Azores cable. This was done without mishap and met all requirements. Dr. Buckley is to be congratulated on the conception of the application of a material of high permeability in ocean cables and on the successful development of the idea.

With this new cable, combining speed, accuracy, reliability and the usual secrecy of cable messages, we are now, for the first time, linked by cable to Italy and Spain, and to these we hope in the near future, to add Germany. At that time it is expected that this cable will be operated on the multiplex system with five or six channels. Three or four of these channels will be used by the Western Union, and it is planned that two or three channels will be used by the Commercial Cable Company under agreement with the Western Union. With the present plans, some of the channels will be operated directly from New York to Berlin and Hamburg without manual rehandling. One or more channels will terminate at the Azores. The channels assigned to the Commercial Cable Company will be operated directly from their office in New York to either Germany or the Azores, all this gives some idea of the flexibility of the multiplex system when used on such a cable.

But more important still, the confidence inspired by the performance of this cable has led the Western Union to order another similar loaded cable, this time to connect New York and London. The signals will be automatically repeated at Newfoundland and Penzance, England, so that there will be complete automatic, through operation between New York and London. This new loaded cable will have a still higher operating speed than the present loaded cable, being designed to transmit signals of frequencies up to 75 cycles per second, which corresponds to a speed of 2400 letters per minute with cable code.

We shall have to revise our ideas of cable telegraphy, for this speed is considerably higher than that at which most of the open-wire, land-line telegraph circuits in the United States are being operated today. This cable will probably require two overland circuits to carry its traffic from Penzance—the cable station on the coast of England—to London. Indeed, the traffic-carrying capacity of this cable will be so great that it will be nearly equal to the total capacity of our present seven cables to England. The addition of this cable alone will result in about a 40-per cent increase in the traffic-carrying capacity of all the present North Atlantic cable communication systems.

The operation of these cables with the Baudot code and with a number of channels, each with its own transmitter and printer, will place cable operation upon the same basis as our trunk land lines, with all that that means in similarity of operating methods and apparatus. With this code there is also the possibility of automatically extending some or all channels of such cables by means of our existing land-line system directly to other parts of

1. A. I. E. E. Journal, Vol. XLIV, August 1925, p. 821.

the United States. A new era is here; between points where the traffic is heavy, the old wavy line of the siphon recorder will gradually drop out of the picture.

E. B. Craft: I should like to correct one impression which may have been given by Dr. Buckley's paper. As he has described the problem of the loaded cable it looks too easy; it looks as if all that had been done was to wrap a permalloy tape around a copper wire and then make a high-speed cable of it.

I wish you might appreciate how much more there was involved in this accomplishment than can be brought out in such a brief paper as that to which you have just listened. Years of painstaking effort were required and difficulties were encountered at every step. Precautions had to be taken against any harmful mechanical and electrical effect which might be encountered in laying or operating a cable.

One very interesting feature of the New York-Azores cable which Dr. Buckley has not mentioned is the new type of balanced sea-earth which was developed after an extensive investigation of cable interference. This sea-earth almost completely eliminates the effect of local power disturbances and atmospherics and makes it possible to operate cables efficiently in the most unfavorable terminal locations.

When the development of the loaded cable was undertaken there were no means in sight for efficient operation of such a high-speed loaded cable, even if the problems of the cable itself could be solved. New operating methods and new methods to measure the electrical constants of a loaded cable had to be worked out and new instruments had to be developed for these purposes. When the cable was laid, these instruments were ready and within a few hours after the final splice was made, the successful operation of the cable was demonstrated. Almost every piece of apparatus used in the test and demonstration of the cable was new and specially developed for the purpose. A new type of cable transmitter, working with compressed air, was devised to send messages at speeds many times greater than would be permitted by any previously existing transmitter. A siphon recorder which would record messages at over 2500 letters per minute was devised and made ready for the test. But perhaps the greatest achievement in this connection was the signal-shaping amplifier. This represented an achievement comparable with that of the cable itself. In addition to apparatus for test and demonstration of the cable, operating systems suitable for commercial use were worked out and tested over an artificial line in the laboratory. All of this was done in advance of laying the first cable.

I hope that some of these accomplishments may later be subject to publication, and when all that was done to make the permalloy-loaded cable a success is known, I am sure that you will feel, as I do, no small satisfaction in its having been an American achievement.

T. S. Perkins: It has occurred to me to ask why the air-gap which occurs in this permalloy winding does not largely neutralize the effect of the high permeability of the material?

O. E. Buckley: Professor Perkins has asked why the air-gap between the adjacent turns of permalloy tape does not materially neutralize the effect of the high permeability of that metal? The answer is rather interesting and may possibly surprise some of you. The reason that the air-gap does not introduce much reluctance in the magnetic circuit is that the magnetic lines of induction are not single loops around the conductor, as has sometimes been assumed, but have the form of a helix which takes a large number of turns around the conductor before crossing an air-gap between adjacent turns of the permalloy tape. In the case of a conductor like that of the New York-Azores cable the lines of induction follow the permalloy tape very closely, the pitch of the screw of the lines of induction being only slightly less than the pitch of the tape, with the result that a line of induction follows the tape for about 20 turns around the conductor, then jumps an air-gap between two adjacent turns and continues following the tape in the same direction as before for another 20 turns, when it again slips back across an air-gap. This means that if the permalloy tape were strictly uniform and continuous from one end of the cable to the other and if the cable carried a steady, direct current and was not subject to the effect of the earth's field, the lines of induction would be continuous from one end of the cable to the other.

ENGINEERING AND ECONOMIC ELEMENTS OF TWO-PHASE, FIVE-WIRE DISTRIBUTION[1]

(Chase)

Saratoga Springs, N. Y., June 25, 1925

A. H. Kehoe: If one first reads the conclusions of this paper (which are carefully drawn) he is apt to take a more generous view of the statements which appear earlier in the text. For instance, the emphasis on cost of making system changes is well placed.

Concerning the subject of a combined light and power system, we believe it can be demonstrated that starting *de novo*, the advantages and disadvantages of two- and three-phase will be so nearly balanced that any difference in cost is well within the accuracy of the original assumptions. In practical applications, however, there are three factors which should always receive consideration—

First, the sources of power and transmission, if these exist, are three-phase, and the country in general is, and will doubtlessly remain, on a three-phase basis for general polyphase utilization. This necessitates the use of special polyphase devices where two-phase, five-wire distribution is adopted.

Second, the three-phase, four-wire system requires an odd voltage according to present standards, for either one or both of the single-phase or polyphase loads.

In addition to the above the adaptation of existing equipment for combined light and power distribution should be accomplished with minimum cost.

In the two locations where two-phase, five-wire light and power distribution systems are contemplated at the present time, there is little doubt that due to the existence of a two-phase system it is much cheaper to retain the two-phase than it is to change over to a three-phase, four-wire supply. These two locations are the exceptions however, and the same elements of cost have the opposite effect on the typical systems of the country which, of course, are three-phase. The systems adopting two-phase, five-wire, will perpetuate non-standard polyphase equipment while the three-phase, four-wire systems will force certain rating compromises but should be able to utilize standard equipment, both existing and new. Just what this later effect will be, depends upon what voltages are selected. The author has everywhere in his paper ignored 120/208-volt three-phase, four-wire which seems to me to affect seriously some of his deductions. This voltage appears to be the only compromise which can be adopted that will allow all existing standard equipment to be utilized successfully.

I have noted such a large number of exceptions in the detailed text of the paper that it would be impossible to comment upon all of them. I shall therefore deal with but four or five matters which seem to be of most importance.

Carrying the matter of "power per wire" to its absurd conclusion, the system proposed by the author is but 80 per cent efficient. However, we all must appreciate the tremendous advantage of the simple three-wire d-c. system. It is the obvious necessity of generating and transmitting polyphase as well as having some polyphase utilization, that makes it necessary to even consider the complications of going to four-wire or five-wire systems to obtain balanced loading on a single system. It may be well, however, to bring out the fact that neutral wires have to be sufficient to carry the unbalance which depends upon the utilization equipment and not the type of system.

1. A. I. E. E. Journal, Vol. XLIV, August, 1925, p. 833.

Under "inherent advantages" on the third page, the question of accommodating phases in separate ducts introduces the element of polyphase motors acting as phase converters while running single-phase. This condition at times of secondary short circuits is one of the problems with which there has not been sufficient operating experience to obtain a positive solution. It seems certain, however, that separate polyphase secondary cables in separate ducts will not improve the hazard which already exists in the matter.

On the fourth page, mention is made of polyphase transformer units. I wish to emphasize this, as in the writer's opinion we have scarcely begun the economic use of polyphase units that will come automatically as soon as the light and power systems are established in a reasonable number of places.

With reference to the Scott connection as a hybrid scheme, some of us who do not agree with the author, believe we are basing our conclusion upon common-sense engineering. Regarding the unbalance due to Scott transformation, it should be realized that this occurs at the source of the supply while the voltage unbalance, set up in the case of secondaries, occurs at the end points of the line. It is doubtful whether any quantity of secondary light and power mains would be installed in the country with spacing as indicated on the fourth page. Our telephone friends might be interested.

In discussing primary voltages higher than 4000 volts, the author speaks of the older natural distrust as if the distribution conditions of the last ten years were not justified. We believe that it has just been demonstrated by a different design of system that it is possible to distribute at the generator voltage and any distrust which has existed in the past was a very proper one for the systems then in use.

R. A. Paine: In the first part of the paper a discussion is given of the fundamental requirements which any distribution system must meet. The field has been covered in a very complete manner but there appear to be several points on which there is disagreement as to just how nearly certain types of distribution systems meet all of the requirements. A comparison has been made in the paper principally between two types of secondary distribution systems, *i. e.*, (1) two-phase, five-wire system and (2) three-phase, four-wire system.

Throughout the paper the voltage of the three-phase, four-wire system has been stressed as being 115/199 volts. This apparently has been done for a purpose. Since the two-phase, five-wire system considered was 115/230 volts, the voltage to ground for the three-phase system for sake of convenience was also selected as 115 volts. We believe the comparison should be made either on the basis of a two-phase system voltage of 120/240 with a corresponding three-phase voltage of 120/208, or on the basis of a two-phase system voltage of 115/230 and a three-phase system voltage of 120/208.

The comparison should be made in accordance with one of the above stated methods because in all cases where a distribution voltage of 115/230 exists it is entirely possible by proper notification to customers, after authority has been received from the public service commission, to raise the voltage to 120/240. If a particular company does not desire to raise its voltage to the above standard, the benefits to be derived from so doing, such as decreased losses on account of the higher voltage, etc., should not be withheld in making a comparative economic study of the two systems.

Accepting this as fact,—namely, that with a three-phase, four-wire system the distribution voltage would be 120/208 volts if operation similar to present practise is followed out,—it should be possible to maintain practically this voltage at the customer's service. Hence, if the motor wiring is at all suitable, voltage at the motor should be well above 200 volts, three-phase. When standard 220-volt motors are used, and assuming the motor terminal voltage to be 205 volts, the efficiency at full load is not materially less than when the motor is operated at 220 volts. The efficiencies at fractional loads will be somewhat higher when the motor is operated below 220 volts. The pull-out torque will be reduced to roughly 86.6 per cent of the pull-out torque at 220 volts. Assuming the pull-out torque value to be 250 per cent of normal full-load torque, and the motor is operated at rated voltage, the new figure will be approximately 217 per cent which should prove ample.

There should be no trouble in operating three-phase motors at 120/208 volts, since the heating of the motors should not be materially increased and because the majority of motors operate at somewhat less than their rating. Further advantage may also be taken due to the fact that the motors are rated on a 40-deg., ambient temperature basis and the usual ambient temperatures encountered are somewhat lower than this figure.

A study of the performance curves of present-day motors indicates that motors rated at 220 volts are apparently designed for a voltage between 200 and 210. Unless the design of motors is changed, cases where 220-volt motors will not operate entirely satisfactorily at 205 volts will be very rare.

The "Outstanding Features" of a two-phase, five-wire distribution system which have been outlined in the paper are, with two exceptions, equally applicable to a three-phase, four-wire system. Of these exceptions one, (namely, use of 208 volts three-phase as the motor voltage for the three-phase system as against 230 volts for motor voltage of the two-phase system) is not a serious disadvantage, if it can be called a disadvantage at all. This is on account of the reasons given above. The second exception, (namely, the use of three transformers per bank for the three-phase system instead of two transformers per bank for the two-phase system) is, of course, somewhat of a handicap in the case of the three-phase system. Usually, however, there is considerable flexibility possible in the manner in which loads are cared for in the three-phase system so that this disadvantage can probably be compensated for.

Voltage unbalances which take place or are inherent in a three phase, four-wire system are in all cases extremely small and practically no difficulty is encountered from an operating standpoint in satisfactorily compensating for them.

This suggestion is made in the paper that a common set of secondary mains be used for supplying both power and lighting loads. This practise is quite commonly followed by several companies at the present time. From the economical point of view, it is very desirable and works out very nicely in practise except in cases where extremely severe conditions are imposed upon the circuits by some types of power load which necessitates separate sets of mains for the power and lighting loads. Stress has been placed upon the saving in the capacity of mains due to diversity between lighting loads and power loads. Any saving due to diversity of load in this part of the system will be exceedingly small as a rule. While the value of diversity is exceedingly great it is felt that the actual diversity existing in the part of the system being discussed in this paper is generally greatly over-estimated. The character of the service which must be rendered has a far greater effect upon the design of the secondary mains than does diversity. Any advantage which might exist in certain special cases may be realized equally well for either the two-phase or three-phase distribution system.

An advantage is claimed for the two-phase, five-wire system, particularly in underground districts, in that multiple-conductor cable can be more readily utilized than with the three-phase system. While this might be an advantage in some cases it would be obtained at the expense of lower quality of service due to the fact that any trouble in the cable would effect a larger number of customers than if single conductor cable were used. The three-phase, four-wire system has a very distinct advantage over the two-phase, five-wire system in underground districts in that for the same power to be transmitted four single-conductor cables of somewhat larger size can be installed instead of five

single-conductor cables with considerable economy in investment and duct space occupied.

In the case where secondary circuits are extended into new territory a three-wire, open-Y, 120/208-volt installation may initially be made. This arrangement is the equivalent of installing a three-wire, 115/230-volt, secondary line in the two-phase system. If later, polyphase service is required it is necessary only to run an additional wire or cable, while with the two-phase system to render polyphase service two additional wires must be installed.

Referring to Table No. 4, it is seen that the total annual cost of the three-phase, four-wire primary, three-phase, four-wire secondary system is approximately 7 per cent less than the two-phase systems shown as Nos. 1 and 2 in the same table. This amounts to upwards of $30,000 annually. Capitalizing this saving at 12½ per cent the above figures correspond to an investment saving of about a quarter of a million dollars.

With regard to all of the points at issue, it may be confidently stated that the three-phase, four-wire distribution system with voltages 120/208 is quite able to hold its own with the two-phase, five-wire system with voltages 115/230 and has the decided advantage of using recognized standard apparatus, including three-phase motors. It is very likely that future developments and refinements will benefit the three-phase system to a greater extent than they would benefit the two-phase system since developments are usually made for the benefit of the majority.

In discussing a common system of a-c. secondary mains for both lights and motors, the author suggests stricter requirements in motor-starting currents. If lower starting currents than now exist are a requisite for any particular type of distribution system, all factors entering into the problem should be carefully evaluated as, in general, the larger the permissible starting current, the lower the cost of the motors. In Brooklyn the use of a combined lighting and power secondary is practically universal and has been for a great many years. We have made our motor-starting current requirements very broad and have found that we have encouraged the use of electricity as a power source, by lowering the customer's initial investment. Any motor installation conforming with the 1923 N. E. L. A. Motor Rules is accepted. In addition, we shall accept motor installations having starting currents in excess of these rules, provided no objectional voltage fluctuations are experienced by other customers connected to the same secondary, as the customer having the large starting current. We believe that all forward looking engineers should plan and design their distribution systems so that any motor installation meeting the requirements of the 1923 N. E. L. A. Rules, is an acceptable installation. When distribution systems are brought up to this standard we may be able to lower still further the initial costs of motor installations, by broadening the present motor rules.

H. R. Woodrow: Mr. Chase's paper attacks the problem from the standpoint of the existing system and for a new layout he is in agreement that the two-phase system is more costly than the three-phase.

In attacking a remodeling problem for a rapidly growing system, I should like first to see how we should develop the system without limitations of existing equipment and then determine how the new layout can be worked into the existing plant or the existing plant worked into the new system, for in a 10- to 12-year period the existing equipment is only one-third of new additions required.

The statement is made in the paper, "If there is any virtue in the number of phases surely it should compare favorably with the three-phase." It would seem to me that this should represent an indirect function in place of a direct one, as the best system, if it gives the same economy, would be a single-wire system.

Referring to the second page, the number of wires per customer would, in many cases, more nearly represent the cost than the power carried per wire, as in the majority of cases the limitation is determined by the minimum size of wire which is practical from the mechanical strength standpoint. The four-phase, five-wire system has 33⅓ per cent more current-carrying wires per service than the three-phase, four-wire system.

Referring to the tabulation under "Feeders" and the comparison of the three-phase, 2300/3900-volt system with four-phase, the four-phase distribution is 40 per cent more expensive than the three-phase. In the "Mains" the annual cost of the four-phase, five-wire system is represented as 7 per cent greater than the three-phase, four-wire system and the transformers under the 2300-volt heading show an increase in cost of the four-phase, five-wire system as 4 per cent. In other words, the tabulation shows an advantage of from 5 to 10 per cent in annual cost for the three-phase, four-wire system in comparison to the four-phase, five-wire, which is in agreement with the general studies we have made.

The only conclusion to which I can come from the study of the new system is that the central station is required to spend from 4 to 10 per cent more for the four-phase, five-wire system than the three-phase, four-wire without increased economy, and that the customer is required to spend more money to take the service and have increased losses in his system. This condition would naturally produce a rapidly increasing demand for three-phase equipment with a reducing demand for two-phase, and therefore the complications of the two-phase system would become more and more involved each year.

Although these factors favoring the three-phase, four-wire system may not in some cases justify the expense of changing over an existing plant, I do think these factors should be very carefully weighed before definitely perpetuating an inferior system.

P. H. Adams: I think Mr. Woodrow overlooked the fact that Mr. Chase's five-wire circuit is made up of two two-phase, three-wire circuits, using a common neutral. In his comparison of costs, he forgot the fact that each customer is connected as a two-phase, three-wire customer.

I agree with Mr. Woodrow in his criticism of the five-wire, two-phase system as a continuation of something that is inherently bad, and that we should tackle the problem of changing from two-phase, 2400 volts to a higher voltage by considering the existing system as something that will be comparatively small as contrasted with the system five or ten years hence.

We had the same problem in New Jersey, and while our system is a four-wire, two-phase instead of a three-wire, two-phase, as the one with which Mr. Chase has dealt, when we made our change we chose the 4150-volt, three-phase, four-wire system. I think we were right in making this decision, as our system is growing rapidly and in five years we expect to have a system at least four or five times as large as that which existed when we started the change.

L. T. Robinson: I think there is another side that should not be overlooked to this question of distribution systems; that is, that systems and convenience in the arrangement of systems is not everything; you should do as much as you can to make it possible to employ standard apparatus and have conditions under which the apparatus must be used as uniform as possible.

The question of lamp voltages, transformer ratios, the torque and heating of motors, their starting current and efficiency are all involved. While the idea that standard apparatus may be used on both the four-wire, three-phase, and five-wire, quarter-phase systems runs through the presentation and discussion, you must recognize the fact that to the difficulties always present due to the regulation of systems for voltage and frequency, there will be added the conditions of having to meet variable base voltages.

Possibly the apparatus can be successfully made to cover the base-voltage range required as well as the variations found in

practise, but it will be more difficult for the designers, and I feel, to some extent,—I can't say off-hand to what extent—it is going to make the apparatus more bulky and more expensive.

H. Richter: Throughout the paper there are references indicating that the author intended his arguments to apply particularly to areas that now have two-phase distribution, where a combined light and power secondary system is contemplated and it is necessary to solve the involved problem of choosing the type of system best suited to those particular areas. I wish to emphasize the importance of confining the meaning of the paper to such two-phase systems and of not considering it to apply to systems that are now three-phase or to entirely new distribution layouts which may be started in the future.

In my estimation the paper refers almost exclusively to underground and overhead secondary network systems and not to purely radial systems. The idea of extensively using the combined light and power secondary system has been entertained seriously only since the advent of what might be called the latest type of underground a-c. low-voltage network; that is, where a number of primary feeders supply in common an interconnected secondary network. Isolated cases where the combined scheme has been tried out on typical radial systems are known but the majority of companies have kept away from it because, unless an excessive expenditure is made, there is likely to be winking of lights when motors are started and burnout of polyphase motors due to insufficient voltage. It should therefore be recognized that the paper applies only to network systems. The inclusion of overhead secondary systems in the analysis is sound, I believe, for the surprisingly rapid spread of the network idea indicates that in the future, ten to twenty years from now, practically all of the underground systems of the cities will not only be networked but a good portion of the overhead systems will also have networks, possibly in a simpler form and using simpler apparatus.

The comparison has been confirmed to the 115/199-volt three-phase system. I should like to forestall consideration of the 110/190-volt and 125/216-volt, three-phase systems in the discussion. Satisfactory operation of polyphase apparatus on 190 volts would entail so great an expenditure, both in taking care of existing installations and development of new apparatus, that 110/190 volts is practically out of the running. 125/216 volts is also more or less out of the picture, partly because 125 volts is not even a recognized exception as a lamp standard, and partly due to the excessive burden that would be thrown on the industry as a whole by the necessity of developing new lines for the many types of apparatus now standardized at 115 volts or considered satisfactory for operation on 120 volts. The comparison of two-phase with three-phase should therefore be confined to 115/199, or possibly 120/208 volts for the three-phase systems.

Wherever low-voltage networks are being installed or planned the companies are figuring on employing three-phase for the primaries, either at potentials in the class below 5000 volts or at some such higher voltage as 13,200. Even the two companies that have indicated a leaning towards two-phase secondary distribution have expressed the intention of employing 13,200-volt, three-phase feeders for future growth. Consequently, we must keep in mind, as of five or ten years from now, only the comparison of the Scott connection with its attendant disadvantages, for transformer banks serving two-phase as against the straight step-down for three-phase distribution.

While it is true that in the past there has been a general tendency to avoid such high primary voltages as 13,200 for miscellaneous distribution in cities, it is also a fact that this is no longer the case. The change in sentiment has been brought about almost entirely by the ability to employ a simple system of distribution in which all primary protective and sectionalizing devices are eliminated, and the only protective apparatus on the distribution system is a low-voltage device of proved performance.

These remarks have been made in an endeavor to clarify the discussion and in that way, if possible, simplify the comparison of the various network propositions. As Mr. Robinson has said, this is quite necessary for it is extremely important from the standpoint of the manufacturers, customers and, indirectly, the operating companies, that the latter get together without further delay and standardize as far as possible on such a combined light and power scheme as can be used to the greatest advantage on the majority of systems introducing the least possible extra expense in the manufacture and stocking of different types of apparatus.

Even though the including of items for operation and maintenance gaged over a period of ten years would probably have increased the difference in favor of the three-phase secondary system Tables III and IV do not show a large economic advantage for three-phase. Further, it is apparent that despite a weighing of all evidence of engineering and operating nature a balance shows in favor of three-phase, and also, this balance is not large. It is therefore admissible that if the standpoint of the operating company only is considered and the analysis is confined to the usual period of ten years to come, the net advantage of three-phase over two-phase may not be great enough to outweigh the obvious benefits of having a uniform system of secondary distribution throughout a city. In connection with that which follows it should be borne in mind that the greater part of these benefits accrue from the attitude of the public in general.

Likewise, where a large number of two-phase motors now exist in an area that it is proposed to network, it is evident that the expense of changing them over to three-phase, or in all cases providing auto-transformers for a three-phase to two-phase transformation could probably not be counterbalanced even in ten years by the small economic advantage of the three-phase.

However, it is conceivable that in this particular problem, an unusually broad point of view should be applied. The paper touches on the conditions that are tending to make two-phase obsolete. Exact data in this regard are difficult to obtain. There are but two large distribution systems and a few smaller ones still two-phase. The ratio of present investment in two-phase systems to that in all systems in the country may be gaged approximately by the fact that in 1923 only 6 per cent of all the polyphase motors sold by one prominent manufacturer were two-phase. It does not require a stretch of the imagination to foresee that within the next ten or twenty years this percentage is likely to decrease to even half its present value as the tendency for smaller companies operating two-phase to change to three-phase continues and as new systems in rapidly growing parts of the country start up, using the present standard of three-phase. With that reduced percentage of two-phase business it is natural to expect that prices and deliveries of two-phase apparatus will be adversely affected. Thereupon, customers in two-phase areas will set up a demand for three-phase service and this will have to be complied with by the operating companies. At the current rate of load increase, in ten years there will be about four times as many motors on the two-phase systems as at present and in twenty years about sixteen times as many. The expense of changeover to three-phase at that time will be correspondingly greater than at present. Even though measures may be taken to postpone the changeover, these will of necessity have only a temporary effect. The greater the delay the worse will be the situation when the change to three-phase finally takes place.

Coming now to systems where three-phase already exists, enough has been said to prove that it is almost out of the question to expect them to go to two-phase, five-wire secondaries. To review a few of the reasons, there is the great expense of changing three-phase motors to two-phase, replacing three-phase transformer banks by Scott-connected banks, and pulling in a fifth secondary service as well as sometimes in many places riser wire. Where ducts and service pipes are too small for the fifth wire, reconstruction would be necessary.

Finally, there are the companies that will install networks in what might be termed virgin territory. The paper shows cer-

tain definite though small advantages for three-phase, four-wire over two-phase, five-wire, such as in annual charges and first cost. In the majority of cities the cost of operation and maintenance of the two-phase system would be greater, due to the added maintenance of the fifth wire and five-wire protective equipment. There are also the extra losses due to the Scott transformation to two-phase. Three-phase motors and utilization devices are standard while two-phase apparatus is becoming obsolete. In some makes of motors there is quite an appreciable difference in performance in favor of three-phase, assuming operation at rated voltage. Even though the advantages for each of these factors may not individually, be great, when added together they point unmistakably to the wisdom of making networks in all new distribution layouts three-phase.

P. H. Chase: In some of the discussions on my paper there has been a tendency to confuse what is common practise with that which is good, and what is not common practise with that which is bad. Though two-phase, secondary distribution is not so common as three-phase, proper use of the fundamental distribution requirements as yard sticks certainly cannot lead to the opinion expressed by two of the critics that the two-phase system is bad or inferior.

It is interesting to note that advocates of "Three-Phase" are by no means unanimous in their choice of which is best of the various types of three-phase systems. One type requires what one supporter diplomatically calls "certain rating compromises" but these may result in widespread changes to equipment, to standard lamp voltages or to motor ratings. Another type does not afford load balance or balanced voltages to ground. Expensive expedients, such as auto transformers and the like, are offered to overcome these drawbacks in order to adhere to three-phase and continue to render standard voltages to customers.

Most of the operating companies will continue to have the greatest part of their *secondary* load neither two-phase nor three-phase, but two-wire and three-wire, single-phase. In addition, the number of customers supplied with single-phase as compared with those supplied with polyphase service will be greater than the proportion of the actual single-phase and polyphase loads. Any system which penalizes single-phase customers is laboring under a handicap.

The flexibility and adaptability of the two-phase, five-wire system in handling a combination of two-wire single-phase, three-wire single-phase, and two-phase loads, with superior regulation and load and voltage balance, has not been successfully challenged. These valuable advantages have been demonstrated by long experience but are difficult of expression in dollars.

The small percentage of two-phase motors does not tell the story. From early days there has been a general tendency to operate motors on separate secondaries (and often separate primaries) from lighting. Consequently, the motor voltage and number of phases could be determined by considerations relating to and affecting the motor alone. Lighting was two-wire and three-wire, single-phase, because of the utilization devices, simpler metering and lower service costs, which conditions still obtain. The trend of generation and of transmission toward three-phase naturally directed motor development and primary and secondary polyphase distribution along three-phase lines. Accordingly, three-phase motors predominate but lighting has remained single-phase.

Of recent years, the advent of a-c. secondary networks and the advantages of combined light and power secondaries have brought to the front a requirement which was originally unimportant,—that is, the flexible supply from the same secondary polyphase mains of all types of load, at established standard voltages. The three-phase system cannot meet this without expensive changes or doubtful compromises and such expedients as three-wire, open-Y, or four-wire services and polyphase metering for residence lighting. The two-phase, five-wire system now meets this need without change for both radial and network systems.

Standard two-phase motors are neither obsolete nor penalized in price, as reference to motor price-books will show. The adoption of a *new* line of 199-volt, three-phase motors would be a greater deviation from the principle of standardization than the retention of the already established line of two-phase motors.

Three-phase primary distribution can readily be utilized for supplying two-phase secondaries by the Scott connection of transformers which has been proven by years of operation and does not involve a deviation from standard voltages. The Scott connection deserves no more attention or criticism than many of the common modifications to "standard" transformers which are asked for and furnished almost as a matter of course.

We must keep this matter of standardization in mind. Standardization refers particularly to voltage, frequency, capacity, speeds and types of equipment. On the two-phase, secondary, five-wire system, apparatus, equipment and devices are used that are standard as to voltage, frequency, capacity and kind.

From the standpoint of the operating man, the matter reduces down to whether he is giving adequate service at reasonable cost, by adhering to his existing secondary system, and whether—although there may be a slight theoretical differential in cost, if he were starting new—he is justified in paying the high cost of changeover from the existing system. It is universally admitted that the cost of changeover is extremely high because of the cost of changeover of customers' installations. If the theoretical saving, over a long period of years—say ten—does not pay for the cost of changeover, how can a change be justified?

I referred particularly to 115 volts as the lamp voltage. The same relative situation applies to both two-phase and three-phase taking 120 volts instead of 115 volts. Even with 120/208 volts, three-phase, I believe most operating engineers would feel apprehensive about giving 208 volts to motor customers where they are used to receiving 225 to 235 volts for 220-volt motors.

Regarding "power per wire," this comparison indicates the efficiency in using the capacity of the installed wires including the neutral, which as a matter of practise is comparable in size to the other conductors. One critic states that the two-phase, five-wire system is only 80 per cent efficient. This is true as regards the utilization of the installed copper and on the same basis the three-phase, four-wire system is only 75 per cent efficient.

As to the matter of voltage unbalance on three-phase secondary mains, with a wire spacing of 14½ in., I might say the unbalance is not much decreased even with a spacing of 4½ in. such as on a bracket. That can be easily checked by calculation. Whether voltage unbalance is caused at the source or along the mains makes no difference in the effect.

As I think the paper brought out, I favor the higher primary voltages. However, it is true that there has been in the past some distrust at any rate, on the part of the public and some engineers, of the higher primary voltages for distribution.

Comparing systems on the basis of starting off new would be interesting, but hardly justifiable. But the words of the old adage still hold true:—"No matter where you are going, you must start from where you are." That is the point from which my paper started.

In the matter of relative costs of distribution systems and the relative savings in the light of growth, Tables No. III and IV were based, for the particular area under investigation, on a doubling of the present dense load. Whether doubling or quadrupling of load is assumed, there must be taken into account one factor which seems very important—the increasing loads supplied to customers at primary voltage. As larger buildings are erected and the load grows, it does not necessarily follow, particularly in a congested area, that delivery of all the increased load will be at the same low voltage. Often delivery will be at primary voltage, with the customer providing his own transformers and deci-

ding on the voltage and number of phases on his premises. The primary system will probably supply the medium and large customers and thus absorb a large percentage of the increased load, and the secondary system will supply the smaller customers.

Reference has been made by two speakers to the two-phase system as being "inferior" or "inherently bad." Is a system inferior or inherently bad unless it is either extravagant or inadequate with regard to service? The two-phase, five-wire, secondary system is not a "proposed" system, but has been an actual reality for years. It has given adequate service since the inception of polyphase systems and still is giving economical service. It delivers standard voltages, and this cannot be said of some of the present and proposed three-phase systems. It employs standard apparatus. It affords maximum voltage and load balance in the system. It is flexible in growth and adequately serves the customers' conveniences.

Therefore, my conclusions still are:—The two-phase, five-wire secondary system is adequate and economical, and has a recognized place in distribution practise not inferior to any other system. The two-phase, five-wire system as well as any other adequate and economical system, where once established should be continued unless another system presents greatly superior engineering and economic advantages.

THE OIL-CIRCUIT-BREAKER SITUATION FROM AN OPERATOR'S VIEWPOINT[1]

(Stone)

Saratoga Springs, N. Y., June 25, 1925

W. S. Edsall: We feel that there is not a great deal in this paper that can be discussed by the manufacturers, because it is a paper primarily presenting the operators' viewpoint.

This showing of the various conditions of the grounding of the system and generator is going to help the general situation. The effect of grounding upon recovery voltage and the effect of recovery voltage upon the duty of an oil circuit breaker have not been given the attention the subject merits by either the manufacturer or the operator. The manufacturer has known that very severe duties are imposed upon the breaker under high recovery-voltage conditions. The operators in many cases have not known that the systems contained certain combinations of reactance and capacitance which would, under certain conditions, give high recovery voltages.

We feel it important that the recommendation of the Protective Devices Committee regarding definitions for normal voltage, recovery voltage, normal current, etc., should be followed out. The publication of such definitions will tend to call attention to the conditions that exist, and will lead to more accurate application of breakers to the system.

Some European engineering associations have already made definitions that would distinguish between normal voltage and recovery voltage.

O. K. Marti: Mr. Stone brings out in his paper that it would be highly essential, in the future designs of breakers, to have more data regarding four distinguished designs (see his paper under III) since the opinion is greatly divided as to their value. I shall refer below to two designs which European engineers, at present, believe to be the right steps in the right direction, namely—to the application of multiple contacts in series and to the introduction of a resistance into the breaker circuit.

Very little information has been actually published regarding the operation of breakers embodying the above designs. To my knowledge, there are only two references on the foregoing information, the first in a report to the Swiss Commission by Dr. B. Bauer[2] and the second in an article by Mr. G. Bruehlmann[3] in the *Brown Boveri Review*. Both articles are based upon elaborate tests which led to facts not suspected at the time of starting the investigations.

In Fig. 1 herewith is shown an arrangement whereby a protective resistance may be introduced by means of multiple contacts in series, and its effect realized from Fig. 2. An a-c. arc is extinguished at the moment the current passes through zero if the recovery voltage does not increase high enough so that an arc can be struck anew. Thus it may be noted from the oscillograms taken at Section I of Fig. 1 and shown in Fig. 2 that the increase of the voltage immediately after the arc in Section I extinguished, in case of introducing a protective resistance (see curve denoted by 4) was much more favorable than when no

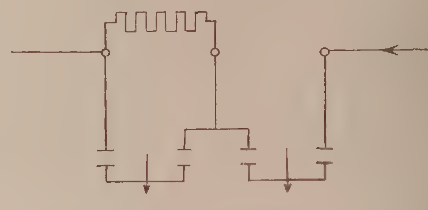


Fig. 1—Diagram of Connection of a Breaker with Protective Resistance

resistance was introduced (see dotted curve denoted by 7). The advantage of the new design lies in the slow increase of the voltage due to the fact that it retards its recovery speed and thus gives the produced arc gases time to cool. Furthermore, there may be noted the very favorable influence of the recovery voltage immediately before the arc extinguishes, having then the value of the ignition voltage. Tests with breakers having various sizes of protective resistances, in addition to many unexpected facts, gave the following results:

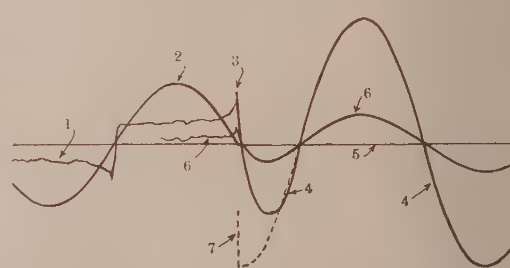


Fig. 2—Voltage and Current when a Circuit Breaker Having Protective Resistance is Tripped by a Short-Circuit as Shown in Section 1

1. Arc Recovery Voltage
2. Arc Current
3. Arc Extinction, Section 1
4. Voltage Across Electrodes and Resistance
5. Zero Line for Current in Arc
6. Current in Resistance
7. Voltage Curve Without Resistance

The best interrupting conditions in any breaker circuit are obtained when a protective resistance eight or ten times the short-circuit impedance is introduced during the short circuit.

The duration of the arc decreased considerably, while the breaker duty, volume of arc gases and the pressure of the oil decreased accordingly. It was actually found in several tests that the released energy in the arc was less than 1/10th.

Other tests which were conducted by the Swiss Federal Railroads on single-pole breakers rated 15,000 volts, 350 amperes, revealed the fact that, in a single tank of less than 5.5 cu. ft.

1. A. I. E. E. Journal, Vol. XLIV, July 1925, page 756.
2. *Bulletin*, Ass. Suisse des Electriciens, 1915.
3. *Brown Boveri Review*, March, 1923, page 43.

volume over 100,000 kv-a. interrupting capacity could easily be handled by introducing in the breaker circuit a protective resistance with multiple-break arrangement. The protective resistance in the above breaker is an integral of the breaker and is inserted in the tank. The result of this test was the adoption of such breakers as standard designs by two state railways in Europe.

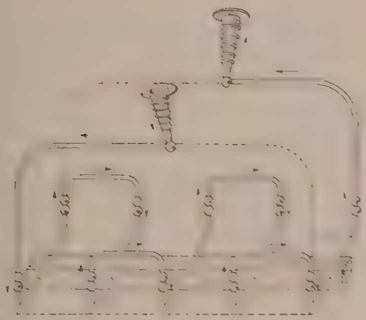


FIG. 3—ARRANGEMENT OF BREAKS AND PATH OF CURRENT IN CASE OF TEN-SERIES BREAKS

The addition of a resistance to a breaker or to the system of a power station should not be considered as a step in the wrong direction in breaker design, since similar steps are being made, at the present time, along this line in protecting electric equipment as, for instance, by the addition of reactors, a limitation of the short-circuit current is obtained.

A schematic arrangement of a multiple-contact breaker is shown in Fig. 3. The purpose of this design is mainly for the reduction of the produced arc gases and the deposit of carbon, the latter causing loss of insulating strength of the oil during interruption. By dividing up the arcing distance, less energy is released and since the gas is produced at several places throughout the oil volume, the latter is therefore, much more quickly cooled. Moreover the arc can be much more easily controlled and, therefore, several dielectric problems overcome without a complicated design. Realizing that 100,000 volts require an arcing distance of over 70 in. the foregoing fact would be greatly appreciated in the design of high-voltage breakers.

It might also be of interest to know that there have been investigations by a European company concerning a new contact device using two series coils so arranged as to form a compact piece of apparatus, which produces a powerful action with a minimum of space. The field produced by these coils closes the breaker against the forces which are especially severe at a short circuit just as easily as at normal load. The forces tending to part the contacts are due to the electrodynamic action and the gases produced between the contacts resulting from the current and the arc. The magnitude of such forces and their influence upon the operation of the breaker and its control mechanism may be better realized after considering the following figures; by breaking a current of about 25,000 amperes and assuming that its maximum value including the asymmetrical component is about 50,000 amperes, the foregoing forces would be approximately 400 lb. which have to be given due consideration in the design of breakers.

The factors determining the duty of a breaker are tabulated under Table IV of Mr. Stone's paper. It follows that the duty depends upon a great number of factors which require a very tedious and rather drawn-out procedure when given due consideration by selecting a breaker. It may be of interest, therefore, to know that a table for ratings of circuit breakers has been published by the Swiss Commission of Oil Circuit Breakers[4] which may be considered as a first step to simplify the foregoing mentioned procedure. This table is shown as Table I herewith and has already been adopted in various parts of Europe.

TABLE I

DUTY IMPOSED ON ONE BREAKER POLE ON TWO- AND SINGLE-PHASE SHORT CIRCUITS COMPARED WITH DUTY ON THREE-PHASE SHORTS

Quantity	Nature of Short Circuit	Short Circuit via transmission lines and transformers: Initial Short equals sustained Short	Short Circuit at generator terminals (without appreciable line impedance): Initial Short	Short Circuit at generator terminals (without appreciable line impedance): Sustained Short
Current interrupted	Three-phase	100%	100%	100%
	Two-phase	$\frac{\sqrt{3}}{2} \times 100 = 87\%$	abt. 100%	abt. 115-150%
	Single-phase	100%	abt. 115%	abt. 150-200%
Voltage	Three-phase	100%	100%	100%
	Two-phase	$\frac{1}{\sqrt{3}} \times 100 = 58\%$	$\frac{1}{\sqrt{3}} \times 100 = 58\%$	abt. 65- 85%
	Single-phase	$\frac{100}{1.5} = 67\%$	$\frac{100}{1.5} = 67\%$	abt. 85-115%
Interrupting capacity	Three-phase	100%	100%	100%
	Two-phase	50%	$\frac{1}{\sqrt{3}} \times 100 = 58\%$	abt. 75-125%
	Single-phase	$\frac{100}{1.5} = 67\%$	c.a. $\frac{115}{1.5}$ 77%	abt. 125-230%

The table is based on the assumption that the impedance of the generators in each phase is smaller by about 15%, on two-phase and single-phase shorts when compared with three-phase shorts, due to the magnetic interlinkage of the phases.

In the last column the first figure refers to low-speed generators, the second figure to turbo generators.

A. H. Kehoe: Many of the large capacity circuit breakers require extrapolation of published test data to establish their rating. This applies particularly to the restoring voltage after final rupture takes place. Future tests of circuit breakers should be with restoring voltage at least equal to the system voltage on which the circuit breaker is to be used, and for some situations double normal voltage should be used on the test circuit in order to obtain correct performance data of the breaker.

4. *Bulletin No.* 2 Ass. Suisse des Electriciens, 1925.

In several places the paper mentions contact resistance at the short-circuit as being one factor to be considered in selecting the size of breaker required. While it may be possible to arrange a circuit so that faults will be in the form of arcs; yet, short-length arcs have voltage drops in the order of 100 to 200 volts for currents from 1000 to 15,000 amperes so that on high-voltage systems contact resistance is negligible. This fact is of importance in considering the destructive forces at a fault, particularly on high-voltage cable systems. Instead of increasing with the voltage, the destructive effect is quite the reverse, as high-voltage lines generally have a considerably lower value of short-circuit current than do the circuits now commonly used.

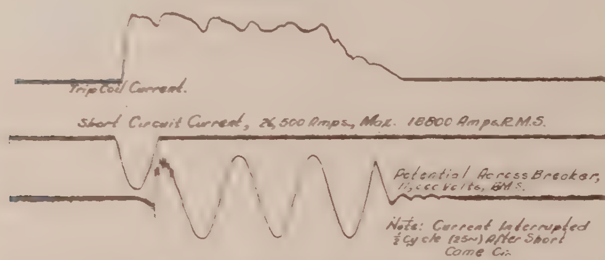


FIG. 4—HIGH-SPEED OIL-CIRCUIT-BREAKER TEST, ALL POSSIBLE LOAD

J. B. MacNeill: On the second page of his paper Mr. Stone gives certain features of design which affect rupturing capacity and states that there exist differences of opinion regarding the merits of some of these features. The general use of certain of these features over a large range of voltage classes and interrupting capacities necessarily results in the application in places where a given principle may not be used to its full advantage as well as in places where the principle may be particularly useful. For instance, the magnetic blowout effect referred to by Mr. Stone is of negligible importance on high-voltage breakers where the current to be interrupted is only a few thousand amperes. On the other hand the use of high-speed breaks on low-voltage breakers where the interrupting current is large, would be entirely superfluous. The best results are obtained when the most effective principle for a particular range of circuit breaker sizes and capacity is limited in its use to such sizes.

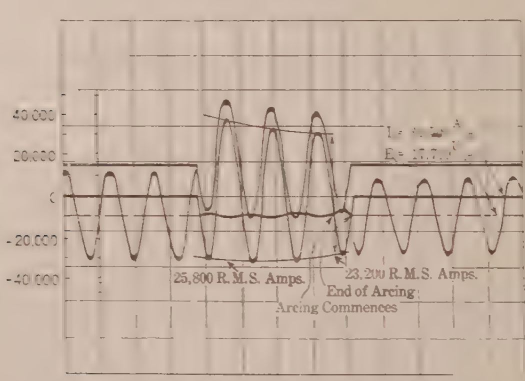


FIG. 5—OSCILLOGRAM OF OIL-CIRCUIT-BREAKER TEST OPENING APPROXIMATELY 25,000 R. M. S. AMPERES AT 13,200 VOLTS, 25 CYCLES

It is generally known that the magnetic blowout effect of the current passing through the loop formed by the contacts and terminals of an ordinary moderate-voltage breaker has a tremendous affect on accelerating the arc formed between the contacts. The length of the arc thus formed may be pretty much independent of the mechanical speed of the breaker although sluggish breaker action is not to be advocated. As an illustration of what can be accomplished with magnetic blowout effects, Fig. 4 herewith shows an oscillogram of a special circuit breaker opening a current of 18,000 r. m. s. amperes on a single-phase grounded circuit at 11,000 volts. The total time of

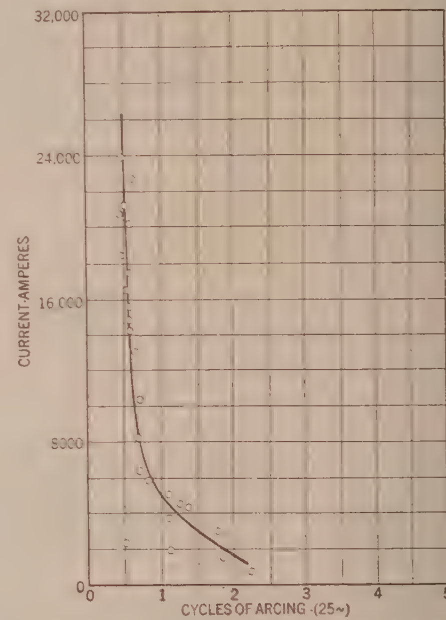


FIG. 6—DURATION OF ARCING AS OBTAINED FROM AVERAGE OF MORE THAN 200 OIL-CIRCUIT-BREAKER TEST OSCILLOGRAMS

operation of the circuit breaker including the tripping time, movement of the contacts and blowing out of the arc, is only one-half cycle on 25 cycles. Fig. 5 shows an oscillogram of a standard circuit breaker of the dead-tank variety opening a current of approximately 20,000 amperes and in which the total period of arcing is approximately one-half cycle on 25 cycles.

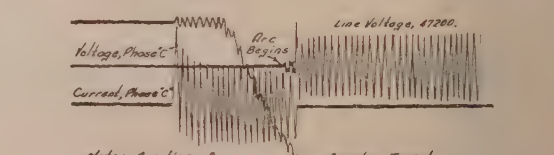


FIG. 7—OSCILLOGRAM OF OIL-CIRCUIT-BREAKER TEST, OPENING APPROXIMATELY 3000 AMPERES AT 44 KV., 60 CYCLES

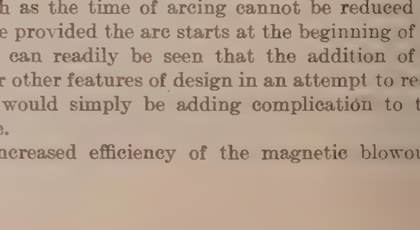


FIG. 8—CIRCUIT-BREAKER TEST

Inasmuch as the time of arcing cannot be reduced below one-half cycle provided the arc starts at the beginning of the voltage wave, it can readily be seen that the addition of high-speed breaks or other features of design in an attempt to reduce arcing further, would simply be adding complication to the breaker structure.

The increased efficiency of the magnetic blowout with in-

creasing currents is shown in Fig. 6 in which ordinates are r. m. s. currents and abscissas are cycles of arcing on a 13,200-volt, 25-cycle circuit. It is evident that the curve becomes asymptotic at one-half cycle. This curve represents the data from a large number of tests on several sizes of breakers and various oil conditions and illustrates the dependability and regularity of operation under these conditions of breakers using this principle.

On the other hand, for high-voltage breakers in which the magnetic blowout effect is inherently small, some device must be resorted to to prevent the building up between the contacts of a pillar of arc gas which may result in an unnecessary long period of arcing. For this purpose high-speed breaks are particularly useful. Anyone who has had the experience of opening an ordinary knife switch will realize the difference that high-speed contacts make on arc duration and the amount of burning on the contact parts. Fig. 7 shows the operation of an ordinary speed breaker at 44,000 volts on opening approximately 3000 amperes at 60 cycles. The arc extends over several cycles which, of course, represents a certain amount of burning of contact parts and oil

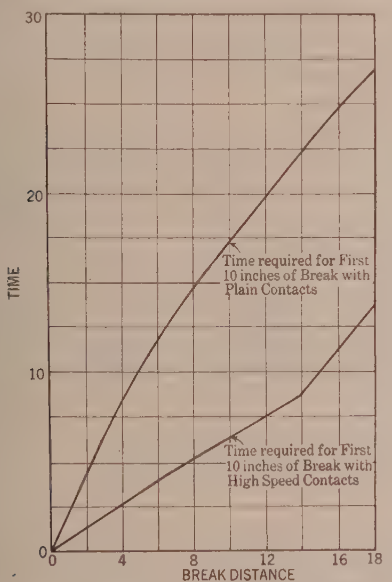


Fig. 9—Relative Speeds of Plain and High-Speed Contacts

and the generation of gas pressure in the breaker structure. In Fig. 8 is shown an oscillogram of a breaker with high-speed contacts opening approximately 4500 amperes at 44,000 volts 60 cycles and, therefore, the amount of arcing can be compared directly to that in Fig. 7. The total duration of arcing with the high-speed contact is 2½ cycles on a 60-cycle circuit and consequently the amount of burning on the breaker contacts, the pressure generated in the tank, and the amount of oil burned up are reduced to a minimum.

Fig. 9 shows curves of the relative speed of the arcing members of a breaker with ordinary breaks and of the same breaker equipped with high-speed contacts. These data were taken with oscillographs but represent mechanical action of the parts only. The time for a given break with high-speed contacts is approximately one-third that required for the same displacement with ordinary break and this ratio holds closely over a large range of voltage classes. Reference to Figs. 7 and 8 indicates that the ratio of arcing period for the two constructions favors the high speed contacts more than does the comparison of mechanical speeds.

M. I. Pupin: In listening to the discussion on circuit breakers, I observed that there was one fundamental principle which I think is never taken account of in the design of circuit breakers. We always take note of the principle of conservation of energy. The energy,—that is, the electrical energy,—must be transformed into some other form of energy. That, of course, is correct. But when you do that, you go only half-way. There is another principle in the science of electricity which must be taken into account, and that is the principle of conservation of momentum. You must provide something which will take up the electromagnetic momentum accompanying, say, 50,000 or 100,000 amperes, and this so far as I can see, is not so easy to do.

Arnold Roth: Perhaps I may take up the question of the voltage. As I am acquainted with the work of the European committee mentioned in Mr. Stone's report, I might tell you how we came to the conclusion to introduce the "recovery voltage" in the duty cycle and in the duty imposed on a circuit breaker.

For the time lag of our relays, we use one second and two seconds, and there are generating stations using four and five seconds. As generally known, there is a very big difference for generating stations between the value of the initial rush of short-circuit current and the sustained value. This difference is due to the decreasing of the field. But there is a second effect of this weakening of the field, that is the decreasing of the induced voltage. It takes place in quite the same relation as the decrease of current and I wonder that more attention has not been given to this fact. As a consequence of this effect, if you have a ratio of 4 to 1 between momentary and sustained short circuit, you might have almost the same relation between the induced voltage at the beginning and at the end of the short circuit. The induced voltage during short circuit is identical with the recovery voltage after rupturing the circuit. That is to say, in a 15-kv. network, you would have at the end of a short circuit a voltage of only 3700. You have a relation between the sustained and the momentary short-circuit kv-a. imposed on your breaker not of 1 to 4, as we used to calculate, but of 1 to 16. That is to say, if you cut the short circuit in four, or to 0.1 sec. for this special case, you would have a difference from 1 to 16 that might be in one case 500,000 kv-a. for momentary tripping and in the other 30,000 kv-a. with time delay. You see a big difference, and it is absolutely necessary to introduce this relation in order to have a clear comparison between different tests and different kinds of breakers.

I would not uphold our European practise to delay tripping as long as we do. I think we shall have to build breakers able to break the initial short circuit. But even for "momentary" breaking, if you analyze the short-circuit tests made, you will find it very difficult to have the whole voltage of your station as recovery voltage in the moment you are breaking your short circuit. That is to say, take a 100,000-volt network, you will always find that if, in the moment of the establishment of the short circuit, the voltage has been 100,000 volts, you will have to break only about 85,000 volts if you don't employ special apparatus to trip the breaker before the short circuit occurs, as is the practise in artificial tests.

One of the reasons of European operating companies for introducing long relay setting might be of some interest. These companies installed breakers for the calculated short-circuit capacity when they built the generating stations; afterwards the short-circuit capacity grew and the breakers were no longer sufficient to break the short circuits. Then the operators gave a very long time-setting to the relays in order to reduce the duty. They had really had some reserve for their breakers in the time setting of the relays.

I shall not say that it is good practise, but it is a practise with which we have to calculate in Europe, and to make possible the calculation, we recently introduced the definition of the recovery voltage into our regulation. I would not dare to say that this manner of calculation has become general practise, but we hope it may.

I should like to ask you some questions. I have had opportunity to see many of the leading engineers of this country and have been astonished to find how different are their opinions on the actual situation of the short-circuit-breaker question. I have been in companies where they told me it was quite all right and that they had no difficulties at all. Then there were other networks where it was quite the opposite. Now if you calculate in a general way the short-circuit capacity of the different networks and see the general conditions you would think they are the same. Of course, there must be some reason for this different behaviour. I think it would be a very interesting subject to investigate.

Another question is that of secondary explosions. I have heard many times that one of the most important reasons for the blowing up of breakers is the secondary explosion. We used to make some tests on secondary explosions by exploding gas mixtures, and we found that it takes a relatively big spark to cause an explosion. If we only had on insulators those small sparks which we have as "static" or something like that, it would be quite impossible to ignite the gas. I understand that after a breaker has operated, there is a mixture of explosive gas in the tank of this breaker, but I can't understand how you get the ignition. I should be very much interested if it could be explained.

Perhaps it would be interesting to do some work on the voltage drop in the arcs of short circuits. We made a test with two parallel iron tubes as electrodes and a copper wire acting as fuse with some 90,000-kv-a., short-circuit capacity behind 8000 volts induced voltage. We found about the same values of drop in the arc you had here of 2 to 3 per cent, but this was true only for the first ten or twenty cycles, and afterwards the length of the arc grew and the voltage drop became quite considerable compared to the induced voltage of the circuit, so an influence of the arc resistance on the value of the short-circuit current and consequently on the duty imposed on the breaker is possible if the tripping of the breaker occurs in the moment the arc has a great length. The influence was so great that in some cases the arc was extinguished without operation of the breaker. It took the form of a horseshoe growing bigger and bigger, up to a diameter of 15 to 20 ft. and then extinguishing.

O. R. Shurig (by letter): The following discussion refers particularly to the subject of secondary gas explosions. According to Dr. Roth's discussion, data obtained in Europe appear to show that secondary explosions are less likely to occur than American experience has indicated. It is, therefore, the object of this discussion to present some data obtained in this country on the subject of secondary gas explosions.

Secondary explosions in oil-circuit breakers take place when properly proportioned mixtures of air and gases of decomposition from the oil are ignited. Hence the necessary requirements for secondary explosions are:

1. A combustible gas (or vapor).
2. The presence of oxygen (as, for instance, in air),
3. The proportions of gas and air must be within the explosions limits, and
4. A source of high temperature, such as a flame, an arc, or high-temperature gases.

Tests have shown that the conditions for secondary explosions are likely to be met in oil-circuit breakers unless preventives are applied.

It is well known that the *gases evolved during circuit* interruption in oil are combustible and capable of explosion when suitably mixed with air. The analysis of the gases discharged by an arc between brass electrodes under oil (a commonly used mineral switch oil) showed a hydrogen content of the order of 60 per cent by volume at room temperature. Other explosive gases such as methane and ethylene are also present.

An investigation conducted at Schenectady in 1920 and 1921 to determine the *proportions of gas and air required for explosive mixtures* showed that mixtures containing 5 per cent gas or more up to 50 per cent are explosive, while mixtures not within this range of proportions are not explosive.[5]

The *maximum pressures of explosion* were eight times as high as the initial pressures, all pressures being measured in absolute units, in tests made with initial pressures ranging from atmospheric to 40 lb. per sq. in. absolute (*i. e.*, from 0 to 25 lb. per sq. in. gage). In other words, the maximum pressures of explosion for mixtures of circuit-breaker gases and air are, roughly, 100 lb. per sq. in. gage for a mixture initially at atmospheric pressure, and 300 lb. per sq. in. gage for a mixture initially at 25 lb. per sq. in. gage pressure. Mixtures containing, roughly, 20 per cent oil-circuit-breaker gases and 80 per cent air (by volume) gave the highest pressures above indicated.

In regard to the *ignition of the gases*, investigations have shown that high-pressure secondary explosions are brought about not only by an igniting arc, (either the main circuit breaker arc or some other arc reaching the explosive gas mixture), but also by hot gases rising out of the oil and mixing with the air in the air space, *i. e.*, in the absence of an igniting arc. Thus secondary gas explosions are within common possibility unless suitable preventives are applied (to effect cooling of the rising gases, proper confinement of the arc, or elimination of sparks or arcs in the air space).

In addition to special investigations on this subject, the occurrence of secondary gas explosions from each of the causes stated above has been observed on numerous occasions during oil-circuit-breaker tests when the breakers were over-loaded beyond their rupturing capacity or when means for preventing secondary explosions were omitted.

E. C. Stone: I shall refer the question of secondary explosion to the circuit-breaker designers.

With reference to the circuit-breaker situation in transmission net works, present operating conditions probably depend on whether the circuit breakers at the present time are subjected to less or more than the duties which they can stand. In some cases over-capacity breakers may have been originally installed, or the growth may have been slow, while in other cases the breakers, when installed, may have had little factor of safety and systems may have grown very materially since.

I was very much interested in Doctor Roth's statement as to how the consideration of recovery voltage came about in Europe. In this country, two seconds is about the highest relay setting used. This limit has probably been set by the possible physical damage to equipment and disturbances to motor service. It seems to me that if we allowed five seconds duration of short circuit on our systems as they are operated in this country, we would get into all kinds of trouble, both with our executives and with our customers.

The recovery-voltage proposition came to my attention through a comparison of tests made on circuit breakers of the order of 500,000 kv-a. interrupting capacity on systems with dead-grounded neutral with those tested on systems where the neutral was grounded through fairly high resistance. A study of the oscillograms from the two systems brought out very clearly the difference in the recovery voltage under the two different conditions as to neutral grounding.

It seems to me very important, at the present time, that we should give very serious consideration to "recovery voltage." The fact that along the "decrement" curve the recovery voltage decreases as well as the current is another reason why recovery voltage should be given more serious consideration.

5. For the present purpose, the term explosive is defined as capable of rapid combustion in a manner creating a material pressure rise. The maximum velocity of flame propagation was found to be of the order of 30 ft. per sec. as indicated by the experimentally observed time interval between the beginning of the ignition arc and the occurrence of the maximum pressure.

In this discussion the question of rebuilding existing systems has come up. In such a matter economics plays a very important part. We cannot afford to spend a very large amount of money for a benefit from which dividends will not be derived for a good many years in the future. On the contrary, we must see an almost immediate dividend on all money that is to be spent. The "fixed charges" saved in a step-by-step development will often be many times more than the increased cost of such step development.

There was an expression of difference of opinion between Mr. Kehoe and Doctor Roth, with reference to the voltage at the arc in a fault. I am inclined to think that both were right. Mr. Kehoe referred particularly to underground systems where the arc is confined within close limits, while Doctor Roth referred to overhead systems where there is ample opportunity, particularly with a slight wind, for the arc to spread. Our experience on the system with which I am connected indicates quite clearly that the duty on oil circuit breakers on overhead systems is less than the duty on underground systems, where the theoretical maximum short-circuit current is the same in both cases. Perhaps the behavior of the arc as the breaker opens is one of the factors. Short circuits may occur on pole lines, as well as in cables, by failure of two insulators simultaneously, but in this case, if a wooden crossarm is used there is considerable resistance in the short circuit.

One of our men recently reported a failure from lightning on a 66,000-volt line which was rather interesting. He saw the flash start at the insulator on a tower, spread to an arc between wires, which were about 7 ft. apart, and travel down the span for probably 15 ft. or more, after which the arc broke. It was, however, immediately reestablished at the insulator and the same action occurred again. This was repeated several times until the opening of circuit breakers cleared the line. If the circuit breaker had opened at the moment the arc was broken its duty would have been, of course, light. This illustrates the possibilities that are to be found on overhead systems where an unstable arc is involved.

A CORRECTION

To the Editor:

It has been called to may attention that the date of my Birmingham paper was given as February 16, 1925 in my discussion as printed in the September issue of the JOURNAL, instead of February 16, 1924. I regret to state that the mistake was made in my office, as this date is of considerable importance as a matter of record.

H. WEICHSEL.

ELECTRICITY RECLAIMS NEW ENGLAND FARM LAND

At Turners Falls, Mass., on a tract of high, sandy land considered "worked out" and abandoned for farming long ago, the local electric service company has for several years past been conducting a model electrically irrigated farm. Now approximately 20 acres are under cultivation and produce an income of from \$400 to \$500 an acre. Water for this irrigation is pumped from the Connecticut River, 175 feet below the level of the farm, by electrically run irrigation pumps. Not only is this farm producing garden "truck" but also high grade leaf tobacco and small fruits.

ILLUMINATION ITEMS

By Lighting and Illumination Committee

NEW POSSIBILITIES FOR THE PHOTOELECTRIC CELL

In the past the photoelectric cell has been adapted to photometry with varying degrees of success, but in almost every instance the apparatus required in such an adaptation has been too sensitive in its operation to make it readily usable in the commercial laboratory where speed and ease of operation *are as important as accuracy*, but this new method of photoelectric photometry bids fair to become widely used in the photometric laboratory. In the adaptation of the photoelectric cell to the commercial laboratory there are several difficulties to be overcome. The first of these concerns the fact that no form of photoelectric cell yet produced has the same color-sensitivity curve as the eye. Therefore, of two lights of different color which the eye might evaluate as being of equal intensity, the cell would show the whiter light to be of the higher intensity. This difficulty is almost entirely eliminated through a comparison between two lamps of the same color.

Another difficulty is that the resistance of the cell is so high that it allows only a very small photoelectric current to pass through; hence, the resistance variation due to the light falling upon it will cause a correspondingly small variation in the potential drop across the cell. This change is so small that some means of amplification may be essential if the variation is to be of any practical value. The method of the three electrode tube was chosen as the most effective amplifier since the minute changes in the potential drop across the cell can be used to affect the grid circuit of a suitable amplifying tube so that an easily measurable variation of the plate current will result.

No matter what kind of a photometer is finally decided upon, it must meet the following requirements if it is to be of any practical value:

1. The indications must not be influenced within certain limits by the variation of the color of the lamps photometered. See method herein described.
2. Simplicity of operation comparable with other photometers.
3. Giving results which may be read directly from scale without computations and readjustments.
4. It must not involve the use of a highly sensitive galvanometer or electrometer.
5. Any electrical instrument employed must be easy of adjustment and maintenance.
6. It must not be sensitive to vibration.
7. With a stable zero.
8. Quick of operation.
9. With short period and critically damped.

The practical use of the photometer must not require any manipulation which non-technical operators cannot readily learn to make with certainty and speed. Messrs.

Clayton and Sharp[1] have experimented with the use of the photoelectric cell in the photometric laboratory and have found it possible to make a suitable comparison between a standard lamp and the lamp to be tested, by replacing the ocular photometer plus the eye, by a photoelectric outfit and then by using the cell to determine a condition of photoelectric balance. The procedure by this method is entirely analogous to that used in ocular photometry, namely, starting out with a standard lamp, the position of the movable comparison lamp is adjusted so that its effect on the photoelectric

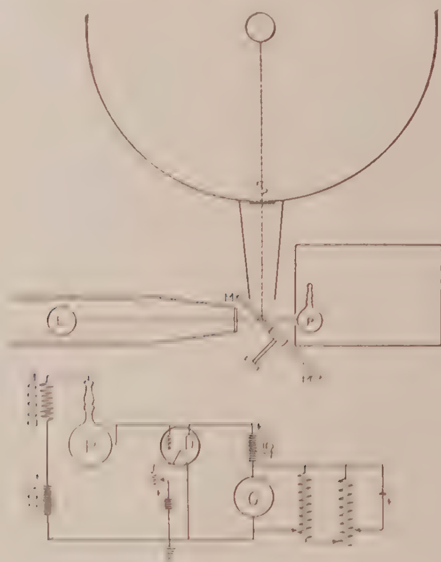


Fig. 1—Photoelectric Cell

cell is the same as that of the standard lamp. Then the photometer scale reads the value of the standard lamp. The lamps to be measured are then substituted one after another, for the standard lamp. The indication of the apparatus is reduced to zero for each lamp by moving the comparison lamp. On the scale is then read the values of the lamp tested.

It is clear that if the measurement on each lamp reduces itself to establishing a zero indication of the electrical instrument, so that no galvanometer deflections have to be observed, the result becomes, within limits, independent of the character of the response curve of the photoelectric arrangement and independent of its sensitivity. The set-up for this means of comparing the standard lamp with the one to be measured is shown in Fig. 1. The position of the mirror M determines whether the cell will be affected by the light from the standard lamp or the lamp to be tested.

A more easily operated photoelectric photometer is shown in Fig. 2. Here the manually-operated mirror of Fig. 1 is replaced by a motor-driven disk upon which are two quadrant mirrors, located opposite each other. Thus, as the disk revolves, the standard lamp and the test lamp are exposed alternately to the cell. The rotation of the disk thus produces a rapid succession of variations of current which give rise to an e. m. f. in the secondary of the transformer T, which is in one direction while the plate current is increasing, and in the opposite direction while the current is decreasing. A commutator, C, is carried on the shaft of the revolving mirror and the galvanometer is connected through this commutator in such a way that if the light from the standard lamp is the greater, the galvanometer deflects in one direction while if the light from the test lamp is the stronger the deflection is in the opposite direction. If the lights are equal in intensity no deflection takes place. This method has the great advantage that with the direct current in the plate circuit eliminated the galvanometer has the same zero, no matter what the value of the plate current may be. Hence, the adjustment of resistances to bring the galvanometer back to zero falls out entirely and any ordinary variations of the plate current, or the filament current, of the amplifier have no influence on the result.

Regular photometric operators who know nothing

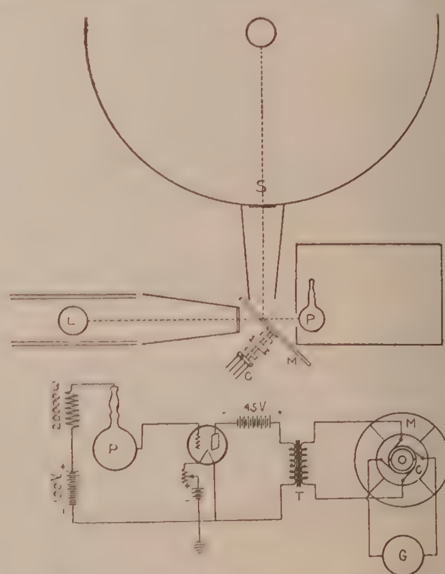


Fig. 2—Photoelectric Cell Position

about photoelectric cells have had no trouble in very quickly learning how to operate this apparatus and the results obtained compare favorably with those secured with ocular photometers. The actual operation of the apparatus consists in merely moving the comparison lamp until there is no deflection of the galvanometer, and then reading the value of the lamp directly from the scale.

The galvanometer is critically damped so that the pointer does not vibrate excessively with the rotation of the commutator, but rather it maintains a more or less steady position according to the relative intensities of the two lamps.

1. "A Practical Form of Photoelectric Photometer"—a paper presented at the Annual Convention of the I. E. S., Detroit, Mich., Sept. 15-18, 1925, by Messrs. Sharp & Kinsley of the Electrical Testing Laboratories, New York City.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Wednesday, October 14, 1925.

There were present: President M. I. Pupin, New York; Vice-Presidents L. F. Morehouse, New York; W. E. Mitchell, Birmingham; W. P. Dobson, Toronto; Managers H. M. Hobart, Schenectady; G. L. Knight, Brooklyn, N. Y.; M. W. McConahey, Sharon, Pa.; E. B. Merriam, Schenectay; H. A. Kidder, New York; National Treasurer George A. Hamilton, Elizabeth, N. J., and National Secretary F. L. Hutchinson, New York.

The minutes of the meeting of the Directors held August 6, 1925, were approved as previously circulated.

A report of a meeting of the Board of Examiners held October 5, 1925, was presented and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken on pending applications: 88 Students were ordered enrolled; 102 applicants were elected to the grade of Associate; 6 applicants were elected to the grade of Member; 3 applicants were transferred to the grade of Member; 4 applicants were transferred to the grade of Fellow.

The Board ratified the approval by the Finance Committee for payment of monthly bills amounting to $31,627.06, which included payment to the Sections of one-half of their appropriations for the year.

The budget for the appropriation year beginning October 1, 1925, was submitted by the Finance Committee and, after consideration, approved.

The Secretary presented a list of members delinquent in the payment of dues for the fiscal year ending April 30, 1925, consisting of five Fellows, 64 Members, and 822 Associates, and was authorized to remove from the membership list on November 1, 1925, the names of all those whose dues remain unpaid at that time and who have not indicated a desire to continue membership requesting an extension of time for payment of the dues.

Upon the recommendation of the Committee on Coordination of Institute Activities, the following schedules of meetings were adopted: Midwinter Convention, New York, week beginning Feburary 8, 1926 (previously approved); Annual Business Meeting, New York, May 21, 1926; Annual Convention, probably June 21-25, 1926, at a place to be decided upon by the Committee on Coordination of Institute Activities; Pacific Coast Convention, Salt Lake City, Utah, at a date to be decided later; Regional Meeting, Middle Eastern District, Cleveland, Ohio, March 18-19, 1926; Regional Meeting, North Eastern District, Niagara Falls, latter part of May or early in June 1926.

Upon presentation of a petition in proper form, authorization was given for the organization of a Saskatchewan Section of the Institute.

The Board authorized the establishment of a Student Branch of the Institute at the University of Wyoming, this having been previously recommended by the Committee on StudentBranches.

A request for authority to organize a Student Branch at Worcester Polytechnic Institute was referred to the Committee on Student Branches with power.

In accordance with Section 21 of the By-laws, consideration was given to the selection of five members of the Board to serve on the National Nominating Committee. The following were selected: L. F. Morehouse, New York; Harold B. Smith, Worcester, Mass.; M. M. Fowler, Chicago; E. B. Merriam, Schenectady; A. G. Pierce, Cleveland.

Resolutions were adopted providing methods for the selection of alternates on the National Nominating Committee, alternates for the Board members on the committee to be appointed by the Executive Committee of the Institute, and alternates for the representatives of the Geographical Districts to be officially designated by the executive committees of the Geographical Districts. It was also ruled that in case any Board member on the committee is also appointed as a representative of a Geographical District, the latter selection will stand and a vacancy will automatically occur in the Board's representation, to be filled by the Executive Committee of the Institute.

The following revisions of the Institute By-laws were adopted:

Section 21—second paragraph. Addition of the clause underlined below:

> "During September of each year the Secretary of the National Nominating Committee shall notify the chairman of the Executive Committee of each Geographical District <u>in which there is or will be during the year a vacancy in the office of Vice-President</u>, that by November 15th of that year a nomination for a Vice-President from the District, made by the District Executive Committee, must be in the hands of the Secretary of the National Nominating Committee."
>
> (Reason: The terms of only one-half of the Vice-Presidents expire each year.)

Section 30. Addition of the clause underlined below:

> "To facilitate cooperation between the Sections there shall be an Executive Committee in each Geographical District, composed of the Vice-President representing the District on the Board of Directors, <u>a District Secretary to be appointed by the Vice-President</u>, and the Chairman and Secretaries of the Sections within the District."
>
> (In accordance with the decision of the Directors at the August 1925 meeting)

The following appointments were made in connection with the American Engineering Standards Committee: Mr. C. E. Skinner

was appointed to succeed himself as an Institute representative for the three-year term beginning January 1, 1926; Mr. L. T. Robinson was reappointed as an alternate representative for the year 1926; and Mr. H. S. Osborne was nominated for appointment to the Executive Committee of the A. E. S. C. for the year 1926.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

Meeting of the New York Electrical Society

The meeting of the New York Electrical Society for November [illegible]l be of unusual interest. It will be the first public demonstra-[illegible]f the new Orthophonic Talking Machines and Electrically Cut Records by the Victor Talking Machine Company. This latest development in the reproduction of sound is almost startling in the progress it represents. At the private demonstrations recently described in the daily press some of the greatest [illegible]ists in the musical world have been unstinted in their praise [illegible]

[illegible] the demonstration, J. P. Maxfield, of the Bell [illegible]s, Inc., will deliver a talk on the technique of sound [illegible]

[illegible] will be held in the Auditorium, Engineering Societies Building, 29 West 39th St., New York on Wednesday November 4th, 1925 at 8 P. M. All interested are invited to [illegible]

Fourth National Radio Conference

[illegible] Fourth National Radio Conference will meet at Washing-[illegible] D. C. at 10:00 o'clock on the morning of November 9th, [illegible] the purpose of discussing and making recommendations [illegible] matters of general radio interest, and it is particularly [illegible]re of Secretary Hoover that the listening public be repre-[illegible]d at this meeting in order that difficulties which listeners [illegible]nter may be made known with an expression of ideas [illegible] the promulgation of betterment of such conditions. [illegible] representation of the Conference will include [illegible] stations, radio magazines and newspaper radio [illegible] manufacturers of complete radio receiving sets, [illegible] of broadcast listeners, amateur organizations, [illegible] and radio stations, radio trade associations, United [illegible] Government Departments, with special representation [illegible]d the Institute of Radio Engineers, and American Insti-[illegible] Electrical Engineers, the American Steamship Owners [illegible] the United States Shipping Board, Farm organiza-[illegible] National Electric Light Association.

[illegible] Conference will to a greater extent give consideration [illegible]n to radio activities generally, specific time and [illegible] be to problems affecting broadcasting.

Annual Meeting of Mechanical Engineers

The preliminary program of the Forty-sixth Annual Meeting of The American Society of Mechanical Engineers November 30th through December 4th holds high promise of profit and pleasure to those in attendance. About forty-five technical papers will be presented, and one special feature of the meeting will be the conferring of Honorary Membership in the Society [illegible]n Honorable Herbert Hoover and Past President Worcester R. Warner. This event will occur on the evening of Tuesday, [illegible]ber 1st, just preceding the Presidential address of Doctor William F. Durand. An innovation at the meeting will be the delivery of the first Henry R. Towne and Robert Henry Thurston Lectures. The Towne lecture will deal with the relation of Engineering to Economics while the Thurston lecture will be on the subject of Engineering and Science. At the Annual Dinner, Wednesday evening, December 2d, the speaker will be one of the [illegible] country. Thursday evening will be given over to a National Defense Session, when industrial leaders will report the progress being made toward perfecting the national program for industrial preparedness.

Appointment of Special Committee on Aviation

Although civil aviation study shows progress, President Coolidge's Aerial Survey Board gives further testimony to the importance and timeliness of the study of aviation now being conducted jointly by a Committee of the American Engineering Council and the Department of Commerce. Of the nine men who met with the President on Thursday, October 18th, two engineers were outstanding in prominence—Doctor William F. Durand of Stanford University, president of The American Society of Mechanical Engineers, member of the National Advisory Committee on Aeronautics and American Engineering Council's Committee on Civil Aviation; and Howard E. Coffin, of Detroit, consulting engineer and expert in Aeronautics. These men were asked, with others, to the White House for the purpose of making detailed study of the best ways and means of developing and applying aircraft. Doctor Durand, at the first meeting, was chosen Secretary of the Board and Dwight W. Morrow the chairman, with Arthur O. Dennison acting as vice-chairman.

Doctor Whitehead Receives Montefiore Medal Award

Doctor J. B. Whitehead, Professor of Electrical Engineering and Dean of the Faculty of Engineering at Johns Hopkins University, has been awarded the triennial prize of the Fondation George Montefiore of Liege, Belgium, for the year 1925, for the best original work contributing to scientific advancement in the technical application of electricity. The prize is awarded for his series of papers entitled, *Gaseous Ionization in Built-up Insulation*. The amount of the prize this year is 4000 francs. This is the second time it has been awarded to Doctor Whitehead, the first award having been made in 1922.

The Fondation George Montefiore was founded by the man whose name it bears, for the encouragement of scientific investigation in the direction of technical application of electricity. It is administered through the Association des Ingenieurs Electriciens, or national electrical engineering society of Belgium, with headquarters at Rue Saint Gilles, 31, Liege, Belgium.

The awarding of the prize is in the hands of a jury of ten electrical engineers composed of five Belgiums and five members from other countries, acting under the President of the Institut Electrotechnique Montefiore, M. M. Omer de Bast.

The Montefiore prize was awarded Doctor Whitehead in 1922 for his paper, "The Corona Voltmeter and the Electric Strength of Air," published in collaboration with T. Isshiki.

American Mathematical Society

The following letter is addressed by the American Mathematical Society to leading members of the electrical engineering profession.

To whom it may concern:

Every Engineer knows the extent to which the technical part of his profession is based upon mathematics. He also appreciates the fact that progress in engineering is becoming increasingly bound up with progress in mathematical science. It is therefore reasonable to assume that he will be interested in whatever contributes to the advancement, and to the greater usefulness, of that science.

The American Mathematical Society is an organiznion devoted solely to the advancement of mathematics. Its membership includes all the leading mathematicians of the country, and its high international position is attested by the fact that it has over a hundred foreign members. Its principal activities today

are the publication of mathematical journals, and the holding of numerous meetings for the stimulation of scientific discussion and of acquaintance among its members.

In order to maintain its activities, and to increase their scope and usefulness, it has seemed to the Council of the Society highly desirable to extend its membership, particularly among technical men.

The Council believes it is justified in appealing to you on the following grounds:

Because the monthly Bulletin of the Society will keep you in touch with the present day developments in Mathematics;

Because membership in the Society carries with it the prestige of an important scientific body;

Because through the membership of technical men, the stimulating effects on mathematics of technical problems, and the usefulness of mathematics to the technical arts, can be greatly enhanced;

Because the establishment of a journal devoted solely to Applied Mathematics, now a desire of the Society, will, with an increased membership among technical men, become both a possibility and a necessity;

Because an effective National Mathematical Society means an increasing number of mathematical works and articles in English, and hence a diminishing dependence of American technicians upon works in foreign languages;—

In short, the Council believes that because you are interested in the present and future of American Engineering, and in the effectiveness and prestige of American Mathematical Science, you will be glad to contribute to the Society at least the support of your membership.

A. I. E. E. Standards

SECTION 30—WIRES AND CABLES NOW AVAILABLE

Since the publication on page 1161 of the October JOURNAL of the list of sections of the revised A. I. E. E. Standards "Available" and "In preparation," Section 30 on "Wires and Cables" has become available. Price, 40 cents. Members of the A. I. E. E. are entitled to 50 per cent discount.

New York Past Section Meeting

The first meeting of the New York Section for the administrative year 1925-26 was held on Friday evening, October 23, 1925, at the Engineering Societies Building with an attendance of about 200. Two papers were presented as follows: *Three-Phase 60,000-Kv-a. Turbo Alternators for Gennevilliers* by C. Roth, Chief Electrical Engineer, Société-Alsacianne de Constructions Mecaniques, Belfort, France and *Hydrogen as a Cooling Medium for Electrical Machinery* by E. Knowlton, C. W. Rice and C. H. Freiburghouse all of the General Electric Co. In the absence of Chairman Kidder, L. F. Morehouse, Vice President of the New York District presided. Following the presentation of each of the papers a very full discussion took place, participated in by engineers of prominence in both the design and operating fields. Among these were Messrs. C. J. Fechheimer, C. M. Laffoon, W. F. Dawson, L. B. Bonnett, Philip Torchio, Dr. Punga.

National Electrical Code

The 1925 Edition of the National Electrical Code has now been released by the National Board of Fire Underwriters. The actual date when it supersedes the 1923 Edition in the review of electric wiring can be determined by inquiry of the authority by whom inspections are made in each respective locality.

The electrical committee of the National Fire Protection Association will meet in February 1926 to consider proposed amendments to the 1925 Edition of the Code in accordance with the program announced when the committee was so enlarged that it qualified as a section under the procedure of the American Engineering Standards Committee.

Recommendations for additions or changes may be received to be routed to appropriate Article Committees for consideration and report at the February meeting. The need for a 1926 Edition of the Code, or a supplement to the 1925 issue, will be determined at this February meeting.

Fourth National Exposition of Power and Mechanical Engineers

The "Power Show" which is now being held at Grand Central Palace under the auspices of the Fourth National Exposition of Power and Mechanical Engineering is presenting an unusually large quota of new devices and apparatus in the power plant field. One of the special features of the Exposition is a series of lectures on the important and outstanding developments in power and mechanical equipment during the past year, with motion pictures illustrative of engineering achievement.

French Executives and Engineers Visit A. I. E. E. Headquarters

A delegation of seventeen French executives and engineers arrived in New York, September 30th under the direction of the Compagnie Francaise Thomson-Houston. A six weeks investigation of American power-plant practise and illuminating engineering is planned. On Saturday, October 3, the delegates visited the Engineering Societies Building, New York, where they were taken to N. E. L. A. headquarters and thence to visit the rooms of the A. I. E. E. Past-President C. O. Mailloux delivered an interesting address to them in French regarding the organization and work of the Institute and its relation to the electrical industries of the country.

The itinerary of the delegation includes visits to places of engineering interest in the principal cities of the United States and extends to the Pacific Coast. On November 7th, the foreign engineers leave New York for home.

The delegation includes the following: Albert Petsche, President, Lyons Water and Light Co., Paul Eschwege, Vice President International Assoc. of Producers & Distributors of Elec., Albert Mercier, President, French Petroleum Company; Auguste Boissonnas, Managing Director, General Pr. & Lt. Co., Albert Malle, President, Electricity Co. of Strasburg; Emile Pinson, Associate Gen. Mgr., Compagnie Générale d'Electricité; Maurice Saurel, Vice President Iberican Electric Construction Co.; Edouard Imbs, President, Society for Development of Illumination; J. A. Arrighi de Casanova, Chief Engineer, Union d'Electricité; Paul Neumier, General Manager, Union d'Electricité; Edmond Aubert, Managing Director, West Sector Lighting Co.; René Hochstetter, General Manager, Société Alsacienne de Constructions Mecaniques; Edouard Roth, Chief Electrical Engineer, Société Alsacienne de Constructions Mecaniques; Robert de Valbreuze, President, Wireless Society; Jean Partridge, Lighting Engineer, City of Paris; L. J. Sartre, Lecturer, University of Paris; Louis Astier, Chief Engineer, Design Dept., C. P .D . E.

National Research Council

HIGHWAY RESEARCH BOND

The fifth Annual Meeting of the Highway Research Board will be held in Washington, D. C., December 3-4, 1925. The program as announced by Charles M. Upham, Director of the Board, features the reports of the Research Committees as well as the final and progress reports to be received from the special investigations now being conducted under the auspices of the Board, covering latest developments in every phase of highway finance, design, construction and maintenance. The meeting will be open to all interested.

U. S. Engineers Meet in England

Out of the joint meeting of the American Institute of Chemical Engineers and the British Institution of Chemical Engineers regular international gatherings of engineers are likely to result. At the Annual dinner recently held in England, it was suggested by Sir Frederick L. Nathan, through Sir Arthur Duckham, who presided that a biennial joint meeting of the two engineering bodies be held alternately in England and America. This should do much to incite helpful cooperation between international engineering factions.

The meeting was preceded by a reception at Leeds University, and the American engineers in attendance made a most interesting trip through Scotland, visited the British Empire exhibition at Wembley and concluded their tour by attending a reception given by Sir Arthur and Lady Duckham at Leighton House to meet the Rt. Hon. Winston Churchill and Lord Balfour.

Meeting of the American Electrochemical Society

Several papers of interest to electrical engineers were presented at the Chattanooga meeting of the American Electrochemical Society, September 24-26. The feature of the meeting was a symposium in charge of Dr. H. C. Parmelee on the "Relation of Electrochemical Industry to the Production of Plant Fertilizers" and this was followed by an inspection trip to Muscle Shoals and the two nitrate plants, which are not in operation.

Recent developments in nitrogen fixation are significant for the engineer because the power requirements are changing as a result of the work of the chemist. Dr. J. M. Braham discussed the present trend in nitrogen fixation with respect to the power used and the kind of nitrogen products which are made available for agriculture.

The production of hydrogen is a problem of increasing importance. Electrolytic hydrogen is in competition with that produced by several other processes including a new one for the preparation of phosphoric acid as well as hydrogen. Hydrogen cells were discussed by W. G. Allen.

Dr. S. Karrer presented a paper on some of the scientific aspects of the arc process for the fixation of nitrogen. This process has found little use in this country, but research on atomic states and the modes of energy transfer give promise of entirely new developments in nitrogen fixation.

Concentrated fertilizer materials, including ammonia, urea, nitric acid and phosphoric acid were discussed by Messrs. Davis, Ross, and Jacobs.

Power supply and the economics of the situation are only a part of the nitrogen problem. Other factors that vitally affect the electrochemical side of this industry are the physical characteristics of the materials produced, their suitability for a variety of crops, the transportation charges, and not least, the reaction of the farmer.

Other papers included a discussion of "Power Resources of the Tennessee Valley" by Major H. C. Fiske and a paper by N. B. Pilling on electrical properties of copper-nickel-manganese alloys which suggests possible developments in resistor materials.

Paris International Conference on High-Tension Lines

It is proposed, subject to there being a sufficient demand, to publish an English edition (in two volumes of approximately 1100 pages each) of the papers read at the International Conference on High Tension Lines held in Paris June 16-25, 1925. The volumes will also contain the discussion which took place.

If the demand reaches 400 copies the price will be four pounds for the two volumes, but in the event of 800 copies being subscribed for, the price will be two pounds ten shillings.

In order that an early decision may be reached as to whether to publish this English edition, those wishing to subscribe for copies are requested to inform without delay

Monsieur Tribot Laspière,
Union des Syndicats de l'Electricité,
25, Boulevard Malesherbes, Paris.

of the number of copies they will require.

A French edition of the papers and discussions will also be published provided subscriptions are received for not less than 1000 sets. The price will be 200 francs per set, but after November 1st, 1925, the price will be increased to 250 francs. Orders for the French edition should also be sent to M. Tribot Laspière at the given address.

Obituary

Harrison Pierce Reed, general manager of the A. Kieckhefer Elevator Company, Milwaukee, Wis., and Fellow of the Institute, died September 27th, 1925. Mr. Reed was born in Milwaukee September 9, 1886, and his early education was through the primary and West Division High Schools of that city. In 1905 he entered Sibley College, Cornell University, and was graduated from the Mechanical Engineering course with a certificate in Electrical Engineering in 1909. He immediately affiliated himself with the Cutler-Hammer Mfg. Co. and continued with them until 1919, taking responsible charge of their respective departments for the Development of Multiple-Unit Battery Car Train-Control, all engineering and Home Office Sales, and the development of new switchgears. He also contributed several valuable patents to this company's workings. In 1921 Mr. Reed left the Cutler-Hammer Mfg. Company to assume the general managership of the A. Kieckhefer Elevator Co., also of Milwaukee, in which capacity he was still active when his death occurred. Mr. Reed was for several years a member of the Institute's Industrial and Domestic Power Committee, serving as chairman of their Subcommittee on Elevators.

J. P. Wintringham, Associate of the Institute since 1889, died suddenly at his home, 153 Henry Street, Brooklyn, N. Y., where he has been carrying on crystallographic, optical and geometrical work for some time.

D. I. Dawbarn, M. E., A. M. I. C. E., was instantly killed in an automobile accident on the morning of October 1st as he was driving to the plant of the Allis Chalmers Manufacturing Company, Milwaukee, Wis., where he was engaged in work for A. Reyrolle & Co., Ltd., Hebburn, England.

Mr. Dawbarn was born July 19, 1896 at Formby, Lancashire, England. He was graduated from the University of Liverpool with first class honors, completing his University course after the conclusion of the war. He then spent a year on electrical research work under The Board of Scientific and Industrial Research, after which time he became engaged with A. Reyrolle & Company, Ltd.

He served his country for nearly five years in the late World War and was Captain of Engineers engaged on electrical communications. Last May Captain Dawbarn came to the United States in the interest of A. Reyrolle and Company, Ltd., and was stationed at the plant of the Allis Chalmers Manufacturing Company, as above stated.

PERSONAL MENTION

John Early Jackson has removed from Schenectady to assume new duties with the Lynchburg Traction and Light Company, Lynchburg, Virginia.

Roderick D. Donaldson, who has been doing consulting engineering work in New York since 1919, has joined the J. G. White Management Corporation, New York City, as assistant chief engineer.

W. H. Curley, formerly electrical and mechanical engineer

for the Sterling Salt Co. is now connected with the operating department of the Long Island Lighting Company, with headquarters at Bay Shore, L. I.

Frank C. Stockwell has been elected Professor of Electrical Engineering at Stevens Institute of Technology. He will continue his practise of consulting engineering in association with H. C. Roters, V. C. MacNabb and H. L. Paulding.

Maxwell W. Day, engineer of the General Electric marine department after 36 years of service retired October 1, owing to the contition of his health. Mr. Day is best known for his work for the federal government in the application of electricity to marine auxiliaries.

R. F. Apeseche, assistant to chief engineer, Anglo-Argentine Tramway Co., Buenos Aires, Argentine, on May 20, 1925, was elected president of the Association of Members of American National Engineering Societies in Argentine. Mr. Apeseche has been an Associate of the Institute since 1916.

Henry H. Norris, who was for ten years on the editorial staff of the *Electric Railway Journal* and later assistant to the president of the McGraw-Hill Company, Inc., has resigned to take up work of vocational education, as educational advisor of the Boston Elevated Railway Company, Boston, Mass. Mr. Norris was at one time professor of Electrical Engineering at Cornell University.

Edward Woodbury has returned from the Baker River Development, in Washington, to the Los Angeles office of Stone & Webster, Inc., to resume his former duties as executive electrical engineer in connection with the addition to the Long Beach Steam Plant being constructed for the Southern California Edison Co. This addition will consist of one unit capable of producing 60,000 kw. and it is expected that its efficiency will be even above the 425 kw-hr. per barrel record of the steam plant recently completed.

Addresses Wanted

A list of names of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—Clyde E. Bentley, 2815 Kelsey St., Berkeley, Calif.
2.—Angus Black, 1237 Pacific St., Brooklyn, N. Y.
3.—Paul H. Burkhart, S S S Yale University, 10 Hillhouse Av., New Haven, Conn.
4.—Manuel W. Dans, Apt. 6, 519 West 134th St., New York, N. Y.
5.—Edward C. Hanson, Dixville, Quebec, Canada.
6.—S. Larios, 143 Fourth St., Milwaukee, Wis.
7.—Robert J. Latorre, 1842 7th Ave., New York, N. Y.
8.—Louis J. McBane, 1336 Oak St., N. W., Washington, D. C.
7.—Willis E. Osborne, 312 West 4th St., Erie, Pa.
8.—Mary Shimanovsky, 24 Mt. Morris Park W., New York, N. Y.
9.—Carl H. Struth, 527 West 124th St., New York, N. Y.
10.—H. Thompson Whaler, 190 S. E. 12th Terrace, Miami, Fla.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

(BOOK NOTICES SEPTEMBER 1-30, 1925)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Aprovechamiento de las Energias Naturales.
By Juan Gelpi Blanco. Barcelona, The Author, 1924. 283 pp., diagrs., tables, 10 x 7 in., cloth. 24 pesetas.

This treatise deals with the utilization of power resources, with special reference to conditions in Spain. It discusses the natural sources of power—winds, waves, tides, streams and fuels - the importance of efficient utilization, the results achieved in modern hydroelectric plants, heat engines, and electric transmission of power. The power resources of Spain are inventoried and attention is called to the need for conservation. Throughout the subject is treated practically, from the point of view of the engineer and the manufacturer.

Beitrage zur Geschichte der Technik und Industrie; Jahrbuch des Vereines Deutscher Ingenieure. 1924. Bd. 14. Edited by Conrad Matschoss. Berlin, V. D. I.—Verlag, 1924. 278 pp., illus., diagrs., ports., 11 x 7 in., paper. 1.75.

The sixteen historical papers in the 1924 volume cover a wide range. There are articles on the history of railroad brakes, of wine-presses, of screw-threads and of chemistry. Biographical contributions include an account of Alfred Krupp as a machine designer; a life of B. H. Strousberg, a German "railway king"; an article on C. Waltjen, one of the pioneers of iron shipbuilding in Germany; and a description of the industrial activity of Emil Kessler, one of the first German locomotive builders. Other articles discuss the history of aluminum, the evolution of wire-drawing machinery, cranes, accumulators and traps and spring-guns. Like its predecessors, the volume is valuable to all who are interested in the history of industry.

Bericht Uber die Diskussionsversammlung des S. E. V. Uber Oelschalterfragen. April, 1925.
By G. Brühlmann, E. Heusser and M. Dutoit. Zürich,

S. E. V. und V. S. E., 1925. (Sonder-Abdruck aus dem Bulletin des S. E. V., no. 2 & 6, 1925). 48 pp., illus., 10 x 7 in., paper. 2,50 fr.

A reprint of three papers on oil switches presented at a meeting of the Swiss Society of Electrical Engineers devoted to that subject. The first, by G. Bruehlmann, is on the theoretical and practical principles underlying the construction, selection and use of oil switches. The second discusses the structural principles underlying the construction of Swiss and foreign oil switches as built at present. The third describes some experiments made with oil switches in actual service.

Coils and Magnet Wire.

By Charles R. Underhill. N. Y., McGraw-Hill Book Co., 1925. 494 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

Although coils are found in every electromagnetic device, specific detailed information on the preparation of magnet wire and on the manufacture and insulation of coils has been difficult to find. This book goes very fully into these questions and other practical matters involved in the construction of coils and should be a welcome addition to the literature on the subject.

Das Deutsche Museum.

Edited by Conrad Matschoss. Berlin, V. D. I. Verlag; München, R. Oldenbourg, 1925. 364 pp., illus., ports., plans, 12 x 9 in., cloth. 20,-mk.

This handsome volume has been issued by the Verein Deutsche Ingenieure as a memorial of the great Deutsche Museum of science and technology at Munich. It gives a short account of its history, of its plan and noteworthy architectural features and of its building. The greater part of the book is devoted to short descriptions of the collections in each section of the Museum. These articles, each by a specialist, not only explain the Museum but are also useful chronologies of the development of the arts and sciences and are profusely illustrated by photographs of the exhibits. Aside from its usefulness as a guide, the book has considerable historical value.

Daedulus; or, Science and the Future.

By J. B. S. Haldane. N. Y., E. P. Dutton & Co., 1924. (Today and tomorrow series). 93 pp., 7 x 5 in., cloth. $1.00.

Mr. Haldane draws an intensely interesting picture of the present trend of science and of possible future developments. His book will stimulate thought along many lines and prove interesting to all educated men. In Mr. Haldane's opinion, the center of scientific interest today lies in biology, and he forecasts great social changes from its applications to our life.

Drafting Methods.

By Douglas S. Trowbridge. N. Y., Codex Book Co., 1925. 155 pp., illus., 8 x 5 in., cloth. $2.50.

The scope of this small reference book is indicated by its contents. The suggestions given and the practices described are intended to promote good practice and efficiency in the drawing-room. The book is not intended as a textbook but rather as a guide to convenient methods and rapid ways of working.

Economics of Public Utilities.

By L. R. Nash. N. Y., McGraw-Hill Book Co., 1925. 430 pp., diagrs., tables, 9 x 6 in., cloth. $4.00.

Contents: Origin and development of public utilities.—Distinguishing characteristics of public utilities.—Franchises.—Capitalization.—Accounting methods.—Regulation.—Valuation.—Depreciation.—Rate of return to investors.—Rate structures.—Taxation.—Tests of utility securities as investments.—Tests of utility development.—Public ownership.—Public relations.—Some current utility problems.—Views on outstanding issues.—Index.

The scope of this work is shown by the table of contents. The aim of the author has been to assemble the essential facts concerning the broader business and economic problems of our public utilities and to analyze and discuss these facts. The discussion is confined to the problems of electric light and power, electric railway and gas properties. It is intended for executives, engineers, city and state officials and others who need a knowledge of the fundamentals of the industry.

Eisenbahnwesen; Die Eisenbahntechnische Tagung und Ihre Ausstellungen, 1924.

Edited by Conrad Matschoss. Berlin, V. D. I.—Verlag, 1925. (Sonderausgabe der Zeitschrift des Vereines Deutscher Ingenieure). 393 + 221 pp., illus., diagrs., plates, 12 x 9 in., cloth.

In 1924 the Verein deutscher Ingenieure adopted a plan for meetings devoted to special branches of engineering, in addition to the general annual meetings. One of these, on railroad engineering, occurred at Berlin, September 21-27, 1924, which was attended by over 5000 railroad men. The papers presented there and the discussions that they provoked are published in this large, bound special number of the "Zeitschrift" and form a good survey of the present state of railroad engineering in Germany.

Among the topics discussed are methods for improving the thermal economy of locomotives, turbine locomotives, the design of electric locomotives, the thermo-locomotive, transportation of bulk freight in dumping cars, electric railroad operation, brakes, ball and roller bearings, powdered coal firing, chilled wheels, American signal systems, classifying yards, standards, modern bridges and tunnels. There is also a description of the exhibition of railroad equipment held in connection with the meeting and a good bibliography of the German books on railroad topics published during the past decade.

Electrical Engineering.

By Clarence V. Christie. 3rd edition, rev. & enl. N. Y., McGraw-Hill Book Co., 1925. 613 pp, diagrs., 9 x 6 in., cloth. $5.00.

A textbook for junior and senior students. The theory and characteristics of electrical machines are developed from the fundamental principles of electrostatics and electromagnetics. The discussion is confined to the standard types of machines, and extensions of subject are left to the instructor, the book being intended only as the foundation for lecture courses.

The new edition has been revised. New information is given on the breakdown of insulating materials, on alternator design, on new motors and on transmission systems.

Die Elektromotoren . . . . v. 1; Gleichstrommotoren, Mehrphasige, Synchronund Asynchronmotoren.

By F. Niethammer. Ber. u. Lpz., Walter de Gruyter & Co., 1925. 100 pp., illus., diagrs., 6 x 4 in., cloth. 1.25 gm.

This little book covers a wide subject most concisely, with the aid of simple mathematical formulas and many graphic charts in the form of switch diagrams and operating curves. It shows how the power, the speed and moment of rotation are determined, how motors are reversed, how their speed is regulated and how they are braked.

Elementary Mathematical Analysis.

By Charles S. Slichter; reset with revisions and additions by Warren Weaver. 3rd edition. N. Y., McGraw-Hill Book Co., 1925. (Modern mathematical texts). 473 pp., 8 x 5 in., cloth. $3.00.

This is not intended to be a text on "practical mathematics" in the sense of making use of scientific material and of fundamental notions not already in the possession of the student or in the sense of making the principles of mathematics secondary to its technique. On the contrary, the aim is to give the fundamental truths of elementary analysis as much prominence as seems possible in a course for freshmen.

The emphasis of the book is placed upon the notion of functionality. Illustrations from science are freely used to make this concept prominent and the student is taught to use mathematics to express and interpret the laws of actual phenomena, not merely to secure here and there certain computed results.

Elementary Mechanical Drawing.

By Charles William Weick; revised by Frank C. Panuska. 2nd edition. N. Y., McGraw-Hill Book Co., 1925. 251 pp., illus., diagrs., 9 x 6 in., cloth. $2.00.

This textbook has been revised in order that the text and problems might conform to the recent developments in the teaching of the subject. A new chapter on sketching has been added and important changes made in various parts of the text. The book is intended to cover theory and practise and to proceed regularly from the elements through the fundamental training needed for general practice in the drafting office.

General Chemistry.

By H. I. Schlesinger. N. Y., Longmans, Green & Co., 1925. 631 pp., diagrs., tables, 9 x 6 in., cloth. $3.75.

Professor Schlesinger's textbook covers the course given at the University of Chicago to students who have had an introductory course in the high school and so are already familiar with the rudiments of the science. In the text attention is concentrated on the fundamental phenomena and principles and on the simpler applications, and these are discussed with some degree of thoroughness. Throughout, chemistry is presented as a growing science in which there are many unsettled questions.

General Physics and Its Application to Industry and Everyday Life.

By Ervin S. Ferry. 2nd edition. N. Y., John Wiley & Sons, 1925. 807 pp., illus., diagrs., 8 x 5 in., cloth. $4.00.

For that large class of students who require a coordinated elementary course in the fundamental principles, the methods and the industrial applications of physics. The purpose is not only to impart information but also to give training in the methods by which facts are correlated in laws and these laws applied to the affairs of life. Attention is given especially to the laws that occur most frequently in ordinary affairs and are most widely applied in the arts, and the illustrative material is selected from engineering, agriculture, etc.

The new edition has been revised and extended by the addition of considerable new illustrative material.

Graphic Table Combining Logarithms and Anti-Logarithms.

By Adrien Lacroix and Charles L. Ragot. N. Y., Macmillan Co., 1925. [56 pp.], 10 x 7 in., cloth. $1.40.

The usual tables of logarithms have the disadvantage that they are essentially "one way" tables, hence interpolation is necessary to find the numbers corresponding to the results obtained in computations. They also give the five-place logarithms of only those numbers that have four places.

The five-place table in this book combines all five-place numbers and all five-place logarithms in one graphic scale from which either can be read in terms of the other, without interpolation. This arrangement makes the table more convenient and reliable than the customary form and enables it to be used more rapidly, the authors state. It also saves, they say, eighty per-cent of the space.

Huiles Minerales pour Transformateurs et Interrupteurs . . . Zurich, l' A. S. E. et de l' U. C. S. 1925. (Tirage à part du Bulletin de l'A. S. E. 1925, no. 4). 28 pp., plate, diagrs., 10 x 7 in., paper. 50,-fr.

This reprint gives the specifications and standard tests for transformer oils adopted this year by the Swiss Association of Electricians and the Swiss Electric Railway Union, and also contains a study by Dr. H. Staeger on the sources and nature of the mineral oils and the methods of testing used in different countries.

Icarus: or, the Future of Science.

By Bertrand Russell. N. Y., E. P. Dutton & Co., 1924. (Today and tomorrow series). 64 pp., 7 x 5 in., cloth. $1.00.

Mr. Russell thinks that science threatens to cause the destruction of our civilization. This little book, which is to a certain extent a reply to "Daedalus," sets forth some of the dangers inherent in science while we retain our present political and economic institutions.

Locating the Iron Trail.

By Edward Gillette. Bost., Christopher Publishing House, 1925. 172 pp., illus., 8 x 5 in., cloth. $2.00.

In 1878 Mr. Gillette joined the staff of the United States Surveys West of the One-Hundredth Meridian, beginning a career of over thirty years of professional work in the west. He took part in railroad location and surveys in Colorado, Utah, Nebraska, the Dakotas, Montana, Idaho, Wyoming and Alaska. His book is one of personal reminiscence, containing accounts of unusual occurrences, adventures and associations, and giving a picture of the conditions met by the pioneer surveyors.

Mitteilungen uber den Osterreichischen Bergbau, 1925.

Edited by Verein der Bergwerksbesitzer Osterreichs. Wien, Verlag für Fachliteratur, 1925. 150 + 60 pp., tables, 8 x 6 in., boards, 8.-mk.

The handbook contains the official statistics on the Austrian mining and metallurgical industries during 1924. It contains statistics of the number of mines and their output; a directory of mines and their officers; a list of idle mines; directories of state departments, professional and commercial associations; tables of exports and imports, etc.

Natural Gasoline, Testing, Manufacturing and Properties.

By G. G. Oberfell and R. C. Alden. [Tulsa, Okla., The Authors], 1924. 533 pp., illus., tables, graphs, 9 x 6 in., fabrikoid. $7.50.

The authors of this work have collected a large mass of data upon the testing, manufacture and properties of natural gasoline, and arranged it in a form convenient for those engaged in the industry. The first section, on testing, gives methods for testing gas, gasoline and absorbent oils. In section two, on manufacture, the application of the fundamental physical laws is explained, and the design and operation of recovery plants, both oil and charcoal, are explained. The physical and chemical properties of natural gasoline are given in section three. Section four contains a miscellany of useful tables and graphs, and a bibliography of books, articles and patents.

Strength of Materials.

By Alfred P. Poorman. N. Y., McGraw-Hill Book Co., 1925. 313 pp., diagrs., tables, 9 x 6 in., cloth. $3.00.

A companion volume to the author's "Applied Mechanics," intended for use in undergraduate courses in mechanics. Contains a large number of illustrative examples with detailed solutions and many problems for solution by the student.

Rewinding Small Motors.

By Daniel H. Braymer and A. C. Roe. N. Y., McGraw-Hill Book Co., 1925. 247 pp., illus., diagrs., charts, 9 x 6 in., cloth. $2.50.

The motors to which this book refers include all those in common use for portable drills, grinders, automobile starters, sewing machines, desk fans, vacuum cleaners, washing machines and similar shop and dwelling equipment. The authors have attempted to compile details about the procedure in winding these motors which will enable an experienced winder to rewind or change them without difficulty.

Railroads; Cases and Selections.

Edited by Eliot Jones and Homer B. Vanderblue. N. Y., Macmillan Co., 1925. 882 pp., diagrs., maps, 9 x 6 in., cloth. $4.25.

This volume is intended to supplement the textbooks of the authors on railroad transportation and rates, by providing a carefully selected body of supplementary material to give concreteness to the principles developed in the more general works on railroad transportation and to stimulate the student to think. The greater part consists of decisions of the Interstate Commerce Commission, the Railroad Labor Board and the Supreme Court of the United States, but historical and critical discussions are also included where they seemed desirable. The material is classified under the Development of the railroad net, Rates, Service, Finance, Combination, Labor and the Conflict of state and nation.

Past Section and Branch Meetings

SECTIONS MEETINGS

Cincinnati

Electrical Methods for the Measurement of Temperature, by L. E. Emerick, Leeds and Northrup Co. September 10. Attendance 36.

Connecticut

High Lights of the Electrical Industry, by L. W. W. Morrow, Managing Editor, *Electrical World*. Refreshments were served. September 25. Attendance 45.

Detroit-Ann Arbor

The Psychology of Laughter, by C. M. Newcomb, Cleveland, Ohio. Dinner Meeting. September 25. Attendance 152.

Erie

The Art of Paper Making, by R. H. Rogers, General Electric Co. Illustrated. September 16. Attendance 70.

Los Angeles

High-Tension Transmission Problems, by C. L. Fortescue, Westinghouse Elec. & Mfg. Co.,

Power Limits on Transmission Systems, by R. J. C. Wood, Southern California Edison Co., and

Problems in Electric Distribution Systems, by D. K. Blake, General Electric Co. Discussion by W. D. Shaw, H. H. Dewey, H. A. Barre, E. R. Stauffacher, C. A. Heinze, M. O. Bolser and E. R. Northmore. A dinner preceded the meeting. October 6. Attendance 138.

Mexico

Short talks were given by several members on their trip to the electrified portion of the Mexican Railway. March 5. Attendance 21.

Business Meeting. May 7. Attendance 21.

Business Meeting. June 4. Attendance 23.

The Future of the Electrical Industry in Mexico, by Mr. Arceo. July 2. Attendance 31.

Why Capital is Lacking to Invest in Mexico on Hydroelectric Installations, by Mr. Larralde. August 6. Attendance 33.

Business Meeting. The following officers were elected: Chairman, E. F. Lopez; Secretary-Treasurer, H. Larralde. September 3. Attendance 31.

Business Meeting. October 1. Attendance 33.

Minnesota

Industrial Lighting, by Ward Harrison, General Electric Co. Joint with St. Paul Electrical Board of Trade. September 22. Attendance 115.

Rochester

Variable-Ratio Frequency Changers, by E. J. Burnham, General Electric Co. Illustrated with slides of the Rochester Gas and Electric Company's frequency changer. Following the paper the meeting adjourned to Station 33 where the operation and control of the units were demonstrated. October 2. Attendance 56.

Springfield

Street and Highway Lighting, by J. H. Lynch, Westinghouse Elec. & Mfg. Co. Illustrated. September 29. Attendance 68.

Toronto

Social Meeting. September 25. Attendance 95.

Vancouver

Inspection trip to the Stave Falls Hydroelectric Plant of the British Columbia Electric Railway Company, Ltd. October 3. Attendance 65.

Washington

Luncheon Meeting. September 15. Attendance 48.

BRANCH MEETINGS

Alabama Polytechnic Institute

Business Meeting. September 16. Attendance 16.

Dialect readings by Mrs. Frazier. September 30. Attendance 17.

Cooperative Electrical Engineering, by Mr. Garlington, student, and

Automobile Head Lighting, by Mr. Gard, student. October 7. Attendance 39.

Bucknell University

Business Meeting. The following officers were elected: President, T. J. Miers; Vice-President, Aldus Fogelsanger; Secretary-Treasurer, C. A. Rosencrans. October 7. Attendance 61.

Clarkson College of Technology

Business Meeting. The following officers were elected: Chairman, W. R. MacGregor; Secretary, L. G. Carney; Treasurer, F. G. Toye. September 28. Attendance 40.

A film on the manufacture of Carter's Ink was shown. October 6. Attendance 30.

Clemson Agricultural College

What the Superpower Plan Means and How It Can Be Carried Out, by C. B. Day,

What America's Water-Power Will Do for the American People, by J. R. Smith, and

Superpower as an Aid to National Defense, by V. C. Sanders. October 8. Attendance 37.

University of Denver

Business Meeting. October 1. Attendance 12.

State University of Iowa

Business Meeting. The following officers were elected: President, Leon Dimond; Vice-President, L. A. Ware; Secretary-Treasurer, A. C. Baeke. September 30. Attendance 39.

The American Institute of Electrical Engineers and the Student Branches, by Professor A. H. Ford. October 7. Attendance 45.

Kansas State College

Testing of Transmission Lines, by Mr. Kerchner. September 21. Attendance 39.

Lafayette College

Business Meeting. The following officers were elected: Chairman, A. H. Gobert; Secretary, Frank G. Keim. September 26. Attendance 21.

University of Nevada

The Hydroelectric Development of Boulder Canyon, by Governor Scrugham. Illustrated. September 16. Attendance 72.

College of the City of New York

Business Meeting. The following officers were elected: Chairman, James W. Wilson; Vice-Chairman, Daniel J. Schneeweis; Secretary, Frank Kulman; Treasurer, Edgar F. Day; Publicity Manager, Benjamin Orange. October 1. Attendance 15.

New York University

Business Meeting. The following officers were elected; President, W. Robert Steeneck; Secretary, Henry A. Weber. October 1. Attendance 10.

University of North Carolina

Social Meeting. G. M. Wilson was elected Treasurer to replace J. Fred Kistler. October 1. Attendance 43.

University of Notre Dame

Business Meeting. September 28. Attendance 55.

Ohio Northern University

Business Meeting. September 16. Attendance 45.

Construction and Operation of Motion-Picture Projection Machines, by L. E. Young, and

Construction of Low- and High-Tension Insulators, by C. Z. Etherton. September 30. Attendance 44.

University of Oklahoma

My Summer Trip to the A. I. E. E. Convention, by Professor E. R. Page, University of Oklahoma. The following officers were elected: President: Floyd O. Bond; Vice-President, Mr. Brady; Secretary, Edw. F. Durbeck, Jr.; Treasurer, Earle E. Jackson. October 8. Attendance 29.

Rose Polytechnic Institute

The A. I. E. E. as an Organization, by Professor C. C. Knipmeyer. The following officers were elected: President, J. H. Utt; Secretary, Everett Letsinger. October 2. Attendance 18.

Rutgers University

Electric Power, by Mr. Aylesworth, and

The Human Side of Engineering. October 5. Attendance 18.

University of Tennessee

Radio Amplifiers, by W. Tadlock, General Electric Co. The following officers were elected: President, Dan H. Sneed; Secretary-Treasurer, Howard B. Shultz. May 14. Attendance 35.

Virginia Military Institute

Business Meeting. The following officers were elected: Chairman, E. T. Morris; Secretary, J. H. Diuguid. June 6. Attendance 50.

Virginia Polytechnic Institute

Business Meeting. September 25. Attendance 38.

West Virginia University

Business Meeting. The following officers were elected: President, R. W. Beardslee; Vice-President, R. L. Cole; Secretary, W. F. Davis. October 5. Attendance 31.

Electrical Development in Australia, by E. L. Hartman,

Gas-Electric Railless Transportation, by W. W. Reed,

Transformers Cooled by Air Jets, by D. S. L. Roush,

Service and Repair Records for Electric Motors, by J. W. Schramm,

Franklin, as a Scientist and Inventor, by K. D. Stewart,

Operating a Fully Interconnecting System, by R. A. Osborn,

Life of Oliver Heaviside, by Glenn Cornell,

Contracting in Engineering, by L. S. Davis, and

Contrast of Electric to Gas Bus, by C. B. Binns. October 12. Attendance 33.

Yale University

Social Meeting. October 6. Attendance 43.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.

53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

GRADUATE ELECTRICAL ENGINEER, young, thoroughly experienced in radio development, and familiar with modern broadcast receiver problems. Should be well versed in shop and manufacturing methods. Location, Middlewest. R-7543.

ELECTRICAL SALES ENGINEER, for company manufacturing carbon brushes and generators, and carbon specialities. Kansas, St. Louis, Mo.; Birmingham, Ala.; Atlanta, Ga. R-5406.

SALES ENGINEER, with acquaintances among engineers of power houses, substations and industrial plants to sell renewal products. Salary and commission. Apply by letter stating experience, education, age, and salary expected. Location, New York and vicinity. R-7404.

SALES REPRESENTATIVE, to take on line of established renewal products salable to power house. Substation and industrial engineers, preferably one with established clientele. Commission basis. Exclusive territory in Pittsburgh, Chicago and San Francisco. R-7405.

SALES REPRESENTATIVE to sell on liberal commission a modern heating system used extensively in the better class of residences, apartment houses and office buildings. Applicant must be familiar with this class of work and acquainted with architects and builders. Location, New York City. R-2149.

SALES ENGINEER, under 30, to sell glass reflectors. Location, New York City and vicinity. R-3135.

SALES ENGINEER, with 2-3 years' experience, with piston rings. Power plant or refrigeration experience considered. Commission. Location, not stated. R-4043.

RADIO RESEARCH ENGINEER, thoroughly familiar with all types of present day circuits. Must be able to analyze all kinds of circuits and suggest changes and remedies for existing defects. Apply by letter. Salary $100 a week. Location, New York. R-7628.

MEN AVAILABLE

GRADUATE IN ELECTRICAL ENGINEERING, age 26, two years' broad experience in maintenance, operation and repair of power equipment, some mining experience, three years' office work with large manufacturer of electrical apparatus. Available on two weeks' notice to present employer. C-436.

CHIEF ELECTRICIAN, fourteen years' experience in the construction, maintenance and operation of industrial plant electrical systems, two years' as chief electrician. Married, 30 years old, technical graduate. Available on fifteen days' notice. Location immaterial. C-441.

GRADUATE ELECTRICAL ENGINEER, 1924, age 29, married, desires a position that will give him an opportunity to become a designer. Experience factory electrician, motor tester, telephone maintainer. Available immediately. Location immaterial. C-314.

EXECUTIVE, technical graduate, age 34, with wide engineering, sales and manufacturing experience. At present managerial head of a small nationally known electrical switch company, but wishes to relocate as manufacturing executive with larger organization. C-462.

ELECTRICAL ENGINEER, commercial and industrial experience. Age 30, married. Experience includes four years with public utility on analysis of statistics, surveys of organizations, investigations of contemplated developments and industrial requirements. B-9273.

ELECTRICAL ENGINEERING GRADUATE, three years' experience with a large engineering firm designing and estimating power stations, desires to connect with growing utility, industrial or contracting concern. Location, in Middle West preferred. C-489.

STUDENT A. I. E. E., extensive technical training, age 22, desires position as student engineer with public utility. Would consider manufacturing or hydro-electric concern. One year's experience controller testing. Location, Western States, preferably Colorado. Salary secondary importance. Available ten days' notice. C-416.

DESIGNING ENGINEER, 28, single, technical graduate, with five years' experience in designing of power plants, substations, industrial buildings and R. R. bridges. Desires transfer with a consulting engineering firm with the object of betterment. Vicinity of New York preferred. B-8852.

ELECTRICAL ENGINEER, E. E., (Wisconsin) age 28, experience in electrical testing and university teaching, one year in charge of 3000 kw. industrial power-plant. Chinese nationality, speaks fluent English. Excellent personality and reference. Desires position with public utility, electrical manufacturer, or contracting engineers. Location anywhere. Available in two months. C-511.

ENGINEER-LAWYER, graduate, single, age 30, ten years' engineering and commercial experience in Europe and America. Desires connection with public utility, holding company or investment house specializing in utility stock, in consulting or executive capacity. C-500.

ELECTRICAL ENGINEER, 34, married, thirteen years' experience superintending and supervising the installation and operation of all types of electrical equipment for power plants, substations and industrial plants. Detailed information on request. Available on short notice. Will only consider position where I can locate permanently. C-502.

ELECTRICAL-MECHANICAL DRAFTSMAN, age 26, married, technical education, field and office experience on machinery and power house construction. Available immediately. Anywhere. B-7666.

ELECTRICAL ENGINEERING GRADUATE, single, age 26, six months' harbor development, one year electrical testing, three years outside plant engineering with telephone company. Very healthy and adaptable. Desires opportunity in hydroelectric or telephone work. Location preferred, Pacific Northwest, or the South. Minimum salary $2400. C-483.

ENGINEERING EXECUTIVE, leaving position in Manila charge electrical station design, installation, sales office, executive merchandising work for G. E. Training electrical Massachusetts Institute Technology, General Electric Test, engineering sales United States and China. Wishes permanent executive engineering position with public utility or factory North East. Married, 35. $3500. C-450.

ELECTRICAL ENGINEER, 22, single, graduate engineer in E. E. '25, desires position with a future where he can gain experience, and at the same time make a fair salary. Either public utility or private enterprise. Location immaterial. C-512.

EXECUTIVE, eleven years' experience in industrial relations; age 43, technical graduate and post graduate degrees. Good organizer, successful in handling men. Specialized in educational and safety organizations. Continuously employed sixteen years. Seeking larger opportunities. Available on thirty days' notice. C-504.

ELECTRICAL ENGINEER, technical graduate, with several years' experience in mechanical and electrical design of small motors. Desires

position with manufacturer in engineering or sales department. Broad experience in experimental and development work. At present engaged in sales work. Available on reasonable notice. Age 36, married. B-9395.

ENGINEER-PHYSICIST, age 33, graduate of several leading universities, on instruction staff of well known institution for five years. Thorough knowledge of mathematical physics, also practical engineer with experience on radio communication. Electrical development desired. New York City, or vicinity preferred. B-165.

ILLUMINATING ENGINEER is available for an offer from a central station, or manufacturer interested in promoting illumination. C-518.

PATENT ATTORNEY, fifteen years' experience, thoroughly familiar United States and foreign practise. Now executive head large successful electrical manufacturing concern, desires to become associated with established firm patent lawyers, or industrial organization where his experience in creating patent situations and organizing and technical research can be utilized. Possesses rare combination engineer-attorney qualifications, with those of successful business career. B-909.

ELECTRICAL AND MECHANICAL ENGINEER, technical graduate, age 40, married; power and lighting contractor and consulting work for fifteen years. Desires position with public utility in new business of operating department with chance for advancement. Prefers Middle West location. C-526.

TECHNICAL GRADUATE in electrical engineering and administration, 1922, age 27, desires engineering or administrative position with a small, rapidly growing, private concern offering a good opportunity for advancement. Three years' experience in the engineering department of a large public utility with whom he is at present associated. Available on reasonable notice. Location, Eastern States preferred. C-516.

MAINTENANCE ENGINEER, technical education, seven years' experience in construction and maintenance of mechanical, electrical, steam and refrigerating equipment in many varied types of industrial plants. Expert in the electrical line, hard worker, with good initiative and planning ability. Salary $100. B-7005.

POWER SALES ENGINEER, specialist in large power contracts, rate analyses and public service commission cases. Available upon thirty days' notice. Minimum salary $6000. B-4221.

SALES ENGINEER, technical graduate, single, employed. Exceptional experience in manufacture, home office and field sales entire line electrical equipment large manufacturer. Sales record shows excellent results in territory having very high sales resistance. Five successful years present company. Executive ability. Philadelphia preferred. Minimum salary $4000. C-540.

ENGINEER-SCIENTIST, age 30, married, educated at M. I. T., three years in chemistry, three years in mathematical physics, graduating in mechanical engineering. Employed as technical report writer for research laboratory of G. E. and as industrial physicist and designer by Corning Glass Works. Executive experience and broad training in commercial subjects. Employed. B-9930.

EDITOR OR STATISTICAL ENGINEER, general scientific and electrical engineering training, including two years' post graduate study. Broad experience writing, editing magazine articles, newspaper articles, booklets, books, advertising literature, etc. Thorough knowledge printing. Experience statistical work, sales promotion, business administration, business efficiency methods as assistant to prominent executive large corporation. Location, New York City, Chicago, or Boston. C-549.

ENGINEER, age 36, graduate M. E. and E. E., thirteen years' experience; three years industrial, ten years public utility, desires position of responsibility requiring technical and administrative knowledge. Power-plant, substation and transmission experience with large companies. Marine steam and electrical experience. B-5842.

ASSISTANT EXECUTIVE, technical graduate, age 33, married, desires connection with progressive company in commercial capacity, or industrial engineering firm. General experience covers manufacturing, time studies, plant layout, distribution systems, costs, sales, advertising and statistical studies of expenses, revenues and other administrative problems. Location, New England, New York. Available reasonable notice. B-9122.

ELECTRICAL ENGINEER, age 28, unmarried, graduate Mass. Institute of Technology, A. B. degree. Experience small central station installations, was Marconi operator before and naval radio electrician during war. Past three years charge instruction radio communication, design, construction, installation, operation radio station large state university. Prefers experimental or development in communication. Location anywhere. C-354.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED OCTOBER 14, 1925

ACKERMAN, GEORGE E., Sales Engineer, Line Material Co., South Milwaukee, Wis.; res., Erie, Pa.

AGOSTINACCHIO, VITO, Tester, Yankee Radio Co. of America, 25 Hoit St., Newark, N. J.

ALLENDE, OCTAVIO ENRIQUE, Student Engineer, General Electric Co., Schenectady, N. Y.

ALVUNG, ROLF, Electrical Engineer, Standard Steel Car Co., Butler, Pa.

ANDREWS, JOHN WATKINS, Consulting Engineer, Florida Citrus Exchange, Tampa, Fla.

ARNOLD, ROBERT M., Secretary, The Arnold Engineering Co., 565 West Washington Boulevard, Chicago, Ill.

BAZARIAN, MINAS HAMPAR, Elec. Testing, Metering & Drafting, Elec. Engg. Dept., Chase Co., Inc., Waterville; res., Waterbury, Conn.

BENNINGTON, ROBERT FRANK, Electric Maintenance, Hub Engineering Corp., 352 W. 50th St., New York; res., Brooklyn, N. Y.

BOSTWICK, JAMES GARFIELD, Supt., City Light & Water Plant, Fort Valley, Ga.

BRADFORD, ARTHUR J., Laboratory Assistant, General Electric Co., Schenectady, N. Y.

*BULLER, FRANCIS HAMILTON, Designing Engineer, General Electric Co., Schenectady, N. Y.

CALDWELL, JOSEPH A., In charge of Distribution & Elec. Equipment, Consolidated Textile Corp., Lynchburg, Va.

CARDER, ROBERT CALLAN, 27 S. George St., Cumberland, Md.

CLEGHORN, RAYMOND R., Operator, Baltimore Copper Smelting & Rolling Co., Canton, Baltimore, Md.

COMBI, UBERTO ANTONIO, Inspector, Transmission Line, Andhra Valley Power Supply Co., Ltd., Tata Bungalows, Kalyan, Bombay Presidency, India.

DEN HARTOG, JACOB PIETER, Engineer, Research Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

DIRKS, VICTOR FRANCIS, Supt. of Meters & Tests, Electric Light Commission, 3rd & Richardson Aves., Lansdale, Pa.

ETIENNE, LEONARD A., Sales Engineer, Industrial Div., Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.

FISHER, WILLIAM BERNARD, Electrical Foreman, Stone & Webster, Inc., Woonsocket, R. I.; res., Bridgeport, Conn.

*FITCH, CLIFFORD SEARL, Electrician, So. California Edison Co., Big Creek, Calif.

FOSTER, NEVILLE C., Purchasing Agent, The Ohio Public Service Co., 1800 B. F. Keith Bldg., Cleveland, Ohio.

FRANKENFIELD, PAUL T., Mechanical Equipment Draftsman, Jacoby & Everett, 623 Commonwealth Bldg., Allentown, Pa.

*FROST, GEORGE, Engineer & Manager, Bristol Electric Light Co., Bristol, N. H.

FUKAWO, EISHIRO, Electrical Engineer, Bureau of Electricity, Dept. of Communications, Tokyo, Japan.

GAMBLE, CARROLL ELLISON, Switchboard Operator, Carolina Power & Light Co., Moncure, N. Carolina.

GLOCK, CHARLES AUGUSTUS, Asst. Test Engineer, Chile Exploration Co., Chuquicamata, Chile, S. A.

GOTTFRIED, HENRY WILLIAM, Contracting & Sales Engineer, Siemens-Schuckert, Oliver Bldg., Mexico, D. F., Mex.

GUMBART, HAROLD ELTING, Dist. Sales Manager, Foreign Dept., Standard Oil Co. of New York, 26 Broadway, New York, N. Y.; for mail, Hongkong, S. China.

HAND, EDWIN WALKER, Electrician, West Penn Power Co., Wellsburg, W. Va.

HANSEN, EDMUND HENRY, Engineer International News Service, 246 W. 59th St., New York, N. Y.

HARBER, FRANK OLLERENSHAW, Draughtsman-Engineer, Switchgear Dept. Metropolitan Vickers Electric Co., Ltd., Manchester; for mail, Stredford, Manchester Eng.

HARVEY, JOHN L., Operating Engineer, Adirondack Power & Light Corp., Schenectady, N. Y.

HEALEY, WARREN C., Sales Engineer, Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.

HENN, WILLIAM FREDERICK, Commercial Engineer, General Electric Co., Witherspoon Bldg., Philadelphia, Pa.

HERBST, R. J., Salesman, Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.

HOGAN, JOHN F., Graduate Student, with Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.; res., Brooklyn, N. Y.

HOLTZBERG, A. G., Draftsman, Switchboard Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.

HON, T. H., Electrical Research Engineer, Thomson Research Laboratory, General Electric Co., West Lynn; res., Lynn, Mass.

HUMPHREYS, JOHN FRANCIS, Public Service Electric & Gas Co., Hackensack; res., Hasbrouck Heights, N. J.

ISELE, HAROLD ADOLPH, Radio Corp. of America, Rocky Point, N. Y.

JACOBSON, MOSES, Colonial Radio Corp., East Ave. & 10th St., Long Island City; res., New York, N. Y.

JANSSEN, HENRY W., Electrical Engineer, International Electric & Mach. Co., 525 So. Los Angeles St., Los Angeles, Calif.

KATO, KENJI, Electrical Engineer, Bureau of Electricity, Dept. of Communications, Tokyo, Japan.

KAUER, ERNEST, Chief Engineer & Secretary, C. E. Mfg. Co., Inc., & Providence Distributing Co., 702 Eddy St., Providence, R. I.
KELLER, HENRY WALLACE, H. T. Underground Cables, Columbus Railway, Power & Light Co., Columbus, Ohio.
KELLERSTEDT, HERBERT P., Student, Pratt Institute, 261 Ryerson St., Brooklyn, N. Y.
KETCHUM, WILLIAM DAVIES, Standardizing Laboratory, General Electric Co., Lynn, Mass.
KEYES, DONALD C., Superintendent, Grangeville Electric Light & Power Co., Orofino, Idaho.
KIDDER, LORENZO Z., Asst. Elec. Engineer, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.
KREBS, WILLIAM WHISNER, Asst. in charge of Rural Extensions, Roanoke Railway & Electric Co., Roanoke, Va.
LEEMAN, WILLIAM JACOB, Electrician's 3rd Mate, U. S. Navy, U. S. S. Concord, c/o Postmaster, New York, N. Y.
LEWIS, DAVID LLEWELLYN, Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburg; res., Wilkinsburg, Pa.
MARKMAN, FREDRIK, Electrical Engineer, Allamanna Telefonaktiebolaget, L. M. Ericsson, Dobelnsgatan 18, Stockholm, Sweden.
MAXWELL, CARL ALLEN, Resident Engineer, Day & Zimmerman, Saxton; res., Huntingdon, Pa.
McCANN, CHARLES SUMNER, Hugh L. Cooper & Co., Wilson Dam, Florence, Ala.
McFADDEN, HARRY CLEVELAND, 56 Irving Place, Passaic, N. J.
McKEE, DONALD EWAN, Electrician, Mech. Dept., Frisco R. R., Fort Worth, Texas.
McKEE, MOSES MILLER, Asst. Electrical Engineer, New York Telephone Co., 204 2nd Ave., New York, N. Y.
McLAUGHLIN, RALPH ALBERTUS, Tester, Western Electric Co., Inc., Magee Bldg., Pittsburgh, Pa.
McSTROUL, LEO, Electrical Contractor, 1813 Peach St., Erie, Pa.
MENA, A. JIMENEZ, Electrical Engineer, Porto Rico Railway, Light & Power Co., San Juan, P. R.
MILLER, HOWARD LEWIS, Electrical Estimator, Woodfield-Thompson Co., 1619 Sansom St., Philadelphia, Pa.
MILLER, OSCAR GEORGE, Sales Engineer, Standard Underground Cable Co., 50 Church St., New York, N. Y.
MINASIAN, GEORGE TALMAGE, Chief, Technical Bureau, Dist. & Inst. Dept., The New York Edison Co., 130 E. 15th St., New York; res., Glen Ridge, N. J.
MIRODDI, SAVERIO, Station Tester, Brooklyn Edison Co., 14 Rockwell Place, Brooklyn, N. Y.
MITTELL, BRENCHLEY, Electrical Engineer, The Gramophone Co., Ltd., Hayes, Middlesex; res., Iver, Bucks, Eng.
MONTGOMERY, ROGER, Distribution Design Engineer, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
MORRONE, ANTHONY, Construction Dept., Brooklyn Edison Co., Brooklyn, N. Y.
MUNN, SYDNEY ALBERT, Engineering Staff, The City of Santos Improvements Co., Ltd., Caixa 4, Santos, Brazil, So. Amer.
MURPHY, MATTHEW FRANCIS, Inspector, Brooklyn Edison Co., 11 Bond St., Brooklyn; res., Oyster Bay, N. Y.
NEWALL, BENJAMIN EDUARDO, Service Engineer, Sleeper Radio Corp., 438 Washington Ave., Long Island City, N. Y.
NOWLAND, LOUIE CLARK, Chief Engineer, Cincinnati & Suburban Bell Telephone Co., 225 E. 4th St., Cincinnati, Ohio.
OLIPHANT, THOMPSON, Charge Engineer, Electricity Dept., Shanghai Municipal Council, 17 Foochow Road, Shanghai, China.
OMHALT, OLAV, Draftsman, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
PASCOE, WILLIAM T., Sr., Switchboard Engineer, Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.
PEIRCE, CHARLES L., Jr., Manager, Electrical Materials Dept., Hubbard & Co., 6301 Butler St., Pittsburgh, Pa.
PETERSON, RALPH WALDO, Asst. Valuation Engineer, Murrie & Co., Inc., 45 E. 17th St., New York, N. Y.
PINERO, GERARDO, Engineer, Porto Rico Railway, Power & Light Co., San Juan, P. R.
POSTAL, HARRY, 1773 Amsterdam Ave., New York, N. Y.
PRIGMORE, D. C., Operating Dept., Bureau of Power & Light, City of Los Angeles, Los Angeles, Calif.
RIPLEY, DUANE LATHROP, Electrical Testing Laboratories, 80th St. & East End Ave., New York; res., Brooklyn, N. Y.
*SERENTIO, JAMES ARTHUR, Contractor, 23 Willow St., Astoria, N. Y.
SHEPARD, ROBERT BLANCHARD, Electrical Engineer, Underwriters' Laboratories, 100 Leonard St., New York, N. Y.
SICONOLFI, MICHELE, Draughtsman, 1998 Madison Ave., New York, N. Y.
STEIN, ALBERT P., Construction Work, Public Service Co. of Northern Illinois, Evanston; res., Chicago, Ill.
STEINKAMP, ALBERT LOUIS, Commercial Engineer, General Electric Co., Ft. Wayne, Ind.
WADE, ERNEST M., Electrical Foreman, Maine Central Railroad, Brunswick; res., Augusta, Maine.
WALKER, ROBERT JOHN, Lieut., U. S. N., Senior Asst. Engineer, U. S. S. Mississippi, San Francisco, Calif.
WATSON, WILLIAM, Asst. Electrical Engineer, Sir W. G. Armstrong Whitworth & Co., Ltd., Deer Lake, Newfoundland.
WETMORE, HAROLD DOUGLAS, Electrical Tester, United Electric Lt. & Pr. Co., 514 West 147th St., New York, N. Y.
WILSON, HENRY EDGAR, Engg. Dept., Carolina Power & Light Co., Raleigh, No. Car.
WONHAM, WALTER RICHARD, Electrical Engineer, Montreal Tramways Co., 16 Cote St., Montreal, Que., Can.
*WOODBURY, EUGENE, Junior Patent Examiner, Div. 51, U. S. Patent Office, Washington, D. C.
YOUNG, CHARLES ESTEL, Equipment Chief, Western Union Telegraph Co., 7th & Walnut Streets, Kansas City, Mo.
ZIA, YOUSSOUF, 740 Langdon St., Madison, Wis.
ZIMMERMAN, LLOYD D., Sales Engineer, Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.

Total 96

*Formerly Enrolled Students

ASSOCIATES REELECTED OCTOBER 14, 1925

BEMAN, RANSOM HAY, Asst. Electrical Engineer, Detroit Dept. of Street Railways, Detroit, Mich.
BOTTIMER, GORDON W., Operating Dept., Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
ERB, WILLIAM, Engineer, Southern Bell Tel. & Tel. Co., 1620 Hurt Bldg., Atlanta, Ga.
MOORE, JOHN THOMAS, Jr., Electrical Engineer, Construction Div., U. S. Veterans Bureau, Washington, D. C.
PROUT, CURTIS, Ass't to Director of Training, Scovill Mfg. Co., Waterbury; res., Watertown, Conn.
WEST, JOHN WALTER, Jr., Service Engineer, American Gas Association, 342 Madison Ave., New York, N. Y.

MEMBERS ELECTED OCTOBER 14, 1925

CHASE, CLADD HOPKINS, Asst. Distribution Engineer, Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.
EDSON, WILLIAM WALTER, Electrical Engineer, Station Engg. Dept., Edison Electric Illuminating Co. of Boston, 39 Boylston St., Boston; res., Newtonville, Mass.
KAMENSKY, MICHAEL D., Asst. Technical Manager, Direction of United Gov. El. Stations, Gogol Str. 14, Leningrad, Russia.
PUMPHREY, FRED HOMER, Technical Engineer, Staten Island Edison Corp., Livingston Power Plant; res., Port Richmond, N. Y.
RAVEN-HART, ROLAND JAMES MILLEVILLE, Telegraph Supt., Transandine Railways, Los Andes, Chile; for mail, Necochea y Peru, Mendoza, Arg. Rep., So. Amer.
SANBORN, CARL ARTHUR, Consulting Elec. & Mech. Engineer, 357 S. Hill St., Los Angeles, Calif.

TRANSFERRED TO GRADE OF FELLOW OCTOBER 14, 1925

AUSTIN, ARTHUR O., Manager and Chief Engineer, Ohio Insulator Co., Consulting Engineer, Ohio Brass Co., Barberton, O.
BENNETT, CHARLES E., Electrical Engineer, Georgia Railway & Power Co., Atlanta, Ga.
DUBILIER, WILLIAM, President and Technical Director, Dubilier Condenser and Radio Corp., New York, N. Y.
JOHNSON, CARL E., Vice-President and Secretary, U. S. Electrical Mfg. Co., President, U. S. Industries, Inc., Los Angeles, Calif.

TRANSFERRED TO GRADE OF MEMBER OCTOBER 14, 1925

GILLER, FREDERICK S., European Plant Engineer, International Western Electric Co., London, England.
TALBOT, HERBERT L., Acting Chief Electrical Engineer, Porto Rico Railway Light & Power Co., San Juan, P. R.
VAN DEVENTER, HARRY R., Vice-President, Dubilier Condenser & Radio Corp., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held October 5 and 16, 1925, recommended the following members for transfer to the grade of membership indicated.

To Grade of Fellow

PANNELL, ERNEST V., Technical Adviser to the British Aluminum Co., New York.

To Grade of Member

BAILEY, EDGAR L., Electrical Engineer, Detroit, Mich.
BARTON, ROBERT C., Engineer on Construction Methods, Pacific Tel. & Tel. Co., San Francisco, Calif.
BROWN, HARRY F., Assistant Electrical Engineer, N. Y. N. H. & H. R. R. Co., New Haven, Conn.
CAMP, C. R., Head Draftsman, Commonwealth Edison Co., Chicago, Ill.
CANNADY, N. E., State Electrical Engineer, Raleigh, N. C.
CODDING, HENRY W., Assistant Engineer, Elec. Engg. Dept., Public Service Production Co., Newark, N. J.
COLEY, WALTER R., Plant Superintendent, Leeds & Northrup Co., Philadelphia, Pa.
CROTHERS, HAROLD M., Professor of Electrical Engineering, South Dakota State College, Brookings, S. D.
D'ALTON, F. K., Assistant Laboratory Engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ont.
DANA, ALAN S., Research Engineer, Kerite Insulated Wire & Cable Co., Seymour, Conn.
DAVIS, LEE I., Test Engineer, Otis Elevator Co., Yonkers, N. Y.

DuBOIS, DELAFIELD, Electrical Research Engineer, Safety Insulated Wire & Cable Co., Bayonne, N. J.
FINCH, FLOYD R., Electrical Engineer, General Electric Co., Pittsfield, Mass.
GAGE, DAVID H., Foreign Wire Relations Engineer, Postal Telegraph-Cable Co., New York, N. Y.
GEORGE, F. R., Engineer of Operation, Pacific Gas & Electric Co., San Francisco, Calif.
HALL, HERBERT S., Electrical Engineer on Valuation, Murrie & Co., New York, N. Y.
HYER, RAYMOND G., Superintendent Design & Construction, Westchester Lighting Co., Yonkers, N. Y.
JOLLYMAN, JOSIAH P., Chief, Div. of Hydro-electric & Transmission Engineering, Pacific Gas & Electric Co., San Francisco, Calif.
KRUG, FREDERICK, Superintendent of Power Production, Porto Rico Railway, Light & Power Co., San Juan, P. R.
MACK, CARL T., Attorney at Law, Patent Causes, Washington, D. C.
MacLAREN, MALCOLM, Professor of Electrical Engineering, Princeton University, Princeton N. J.
McCABE, GORDON B., Technical Engineer, Operating Dept., Detroit Edison Co., Detroit, Mich.
METZENHEIM, HENRY H., Instructor in Electricity & Mathematics, Newark Technical School, Newark, N. J.
MICHETTI, O. D., Lieut. Commander, Engineering, Argentine Navy, Quincy, Mass.
PAXTON, E. B., Engineer, General Engineering Dept., General Electric Co., Schenectady, N. Y.
REID, MEREDITH W., Electrical Engineer, General Engineering & Management Corp., New York, N. Y.
RUSSELL, ROY E., Estimator, Frank J. York Co., Detroit, Mich.
SINGLETON, L. D., Senior Field Electrical Engineer, Braden Copper Co., Rancagua, Chile.
SMITH, LOUIS G., Assistant to General Superintendent, Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
SNYDER, EDWARD B., Manager, Sales & Engineering, Hi-Tension Ins. Div., Ohio Brass Co., Mansfield, Ohio.
SPOONER, HENRY W., Engineer, The Foundation Co., New York, N. Y.
STEMLER, EDWARD J., Chief Operator, Interborough Rapid Transit Co., New York, N. Y.
TALBOT, EMMETT D., Engineer, Bell Telephone Laboratories, New York, N. Y.
TOUR, GREGORY I., Assistant Engineer, Stone & Webster, Inc., Boston, Mass.
TRUEBLOOD, HOWARD M., Engineer, Dept. of Development & Research, American Telephone & Telegraph Co., New York, N. Y.
VAN KIEUKERKEN, J. M., Assistant Engineer, Cleveland Union Terminals Co., Cleveland, Ohio.
VINET, EUGENE, Assistant to Vice-President in charge of Engineering, Middle West Utilities Co., Chicago, Ill.
WOOD, E. M., Assistant Engineer, Hydro-Electric Power Commission, Toronto, Ont.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1925.

Agens, H. M., The Foundation Co., New York, N. Y.,
Armero, J. P., Alabama Power Co., Birmingham, Ala.
Barber, H. O., Puget Sound Power & Light Co., Snoqualmie, Wash.
Bates, L. W., Appalachian Power Co., Bluefield, W. Va.
Best, E. W., De Vilbiss Mfg. Co., Toledo, Ohio
Boothe, E. F., Marshall Electric Co., St. Louis, Mo.
Brand, J., Electrical Engineer, 868 McAllister St., San Francisco, Calif.
Busch, H. W., Ware Radio Corp., New York, N. Y.
Carver, D. W., Brevard County Power Co., Melbourne, Fla.
Cassell, W. L., University of Colorado, Boulder, Colo.
Caylor, R. A., The E. H. Walker Co., Toledo, Ohio
Christie, S. L., Jr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Connolly, R. C., Western Sugar Refinery, San Francisco, Calif.
Conoley, A. G., American Tel. & Tel. Co., Atlanta, Ga.
Corcoran, H. R., Electric Controller & Mfg. Co., Cleveland, Ohio
Crandall, R. J., National Lamp Works, G. E. Co., Nela Park, Cleveland, Ohio
Cullinan, C., Public Service Production Corp., Newark, N. J.
Davis, R. F., American Tel. & Tel. Co., New York, N. Y.
Dean, S. M., The Detroit Edison Co., Detroit, Mich.
Dearlove, T. C., Elec. Engg., 48 Cornwall St., Toronto, Ont., Can.
de Veyher, C., So. California Telephone Co., Los Angeles, Calif.
Diggins, G. J., Jr., Gibbs & Hill, New York, N. Y.
Ditesheim, G. J., Movado Co., New York, N. Y.
Dow, J. L., (Member), Bell Tel. Laboratories, Inc., New York, N. Y.
Dreese, E. E., (Member), Lincoln Electric Co., Cleveland, Ohio
Drushel, R. W., The Ohio Public Service Co., Alliance, Ohio
Eckersley, J., Toronto Hydro-Electric System, Toronto, Ont., Can.
Elberty, R. S., Jr., American Laundry Machinery Co., Norwood, Ohio
Emanuels, H. S., Fairbanks Morse & Co., Seattle, Wash.
Fanaff, P. A., Electrical Work, Toledo, Ohio
Fleming W. R., Commonwealth Edison Co., Chicago, Ill.
Frum, A., 42 W. 66th St., New York, N. Y.
Gardner, J. H., Jr., Capt., U. S. A., Fort Hayes, Columbus, Ohio
Gettess, G. H., The Detroit Edison Co., Detroit, Mich.
Griswold, R. G., Purdue University, West Lafayette, Ind.
Hardy, R. S., Niagara, Lockport & Ontario Power Co., Buffalo, N.Y.
Hoffman, H. J., General Electric Co., Erie, Pa.
Horn, H. G., General Electric Co., Pittsfield, Mass.
Howerth, D. G., Adirondack Power & Light Corp., Schenectady, N. Y.
Hubbard, McC., Southern Utilities Co., West Palm Beach, Fla.
Hubinger, J. E., Jr., Mississippi River Power Co., Keokuk, Iowa
Isaac, A. C. T., General Electric Co., Pittsfield, Mass.
Johnston, R. F., General Electric Co., New York, N. Y.
Kirby, G. R., Alabama Power Co., Albany, Ala.
Koldoff, A. G., Western Electric Co., Cicero, Ill.
Kopatzke, G. A., Wagner Electric Corp., Milwaukee, Wis.
Larson, N. G., The International Paper Co., New York, N. Y.
Leroy, E. R., New York Telephone Co., New York, N. Y.
Lochner, B. R., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
McNair, J. W., United Electric Light & Power Co., New York, N. Y.
Miller, W. G., Electric Bond & Share Co., New York, N. Y.
Milton, R. M., U. S. Engineer Office, Wilson Dam, Florence, Ala.
Myers, F. W., United Power & Light Corp., Hutchinson, Kans.
Mykland, G., 92 Columbia Heights, Brooklyn, N. Y.
Nelson, E. P., United Electric Light & Power Co., New York, N. Y.
O'Shea, M. V., Jr., 529 N. Pinckney St., Madison, Wis.
Palmer, H B., University of Colorado, Boulder, Colo.
Parry, E. M., 202 Howard St., Passaic Park, N. J.
Pettersen, H. C., Commonwealth Edison Co., Chicago, Ill.
Pullen, J. T., Jr., Southern Utilities Co., West Palm Beach, Fla.
Pyle, M., Puget Sound Power & Light Co., Wenatchee, Wash.
Quinn, J. J., Duquesne Light Co., Pittsburgh, Pa.
Richards, K. W., Public Service Electric & Gas Co., Newark, N. J.
Robinson, T. A., Northern States Power Co., St. Paul, Minn.
Roitburd, B., 2905 Grand Concourse, Bronx, New York, N. Y.
Rote, O. C., General Electric Co., Schenectady, N. Y.
Rump, S., (Member), Yarmouthville, Maine
Ruth, C. W., (Member), C. W. Ruth Engineering Co., Chicago, Ill.
Salerno, M. J., 515 W. 111th St., New York, N.Y.
Sandstrom, P. N., Commonwealth Edison Co., Chicago, Ill.
Sayre, E. R., Hart & Hegeman Co., Chicago, Ill.
Schenck, I. P., Day & Zimmerman, Philadelphia, Pa.
Scott, A. H., General Electric Co., Pittsfield, Mass.
Scudder, F. J., (Member), Bell Tel. Laboratories, Inc., New York, N. Y.
Socolofsky, P., Pratt Institute, Brooklyn, N. Y.
Simpson, W. L., Canadian & General Finance Co., Toronto, Ont., Can.
Sivian, L. J., Bell Telephone Laboratories, Inc., New York, N. Y.
Starosselsky, D. V., Brooklyn Edison Co., Brooklyn, N. Y.
Stewart, P. B., Union Gas & Electric Co., Cincinnati, Ohio
Summers, C. H., Jr., Southern Utilities Co., West Palm Beach, Fla.
Summers, C. J., U. S. S. New Mexico, c/o Postmaster, San Francisco, Calif.
Taylor, P. B., Engineering School, Drexel Institute, Philadelphia, Pa.
Thomas, W. A., New York Edison Co., New York, N. Y.
Thomason, F. L., Murrie & Co., New York, N. Y.
Thompson, S. M., Bureau of Power & Light, City of L. A., Los Angeles, Calif.
Tracey, F. S., Lockport & Newfane Pr. & Water Supply Co., Middleport, N. Y.
van Meeteren, W., (Member), Siemens-Mexico, S. A. Mexico, D. F., Mex.
Wilkinson, G. D., Western Union Telegraph Co., New York, N. Y.
Wood, A. R., The Philadelphia Electric Co., Philadelphia, Pa.

Total 89

Foreign

Aschman, G. D., Public Works Dept., Shannon, New Zealand
Bourchier, L. H. J., Radio Telegraphs, Belize, British Honduras
Bracken, H. P., Sao Paulo Electric Co., Sorocaba Falls, Brazil, S. America
Matunaga, Y., Shibaura Engineering Works, Kanasugi, Shiba, Tokyo, Japan
Redpath, R. A., A. D. Riley & Co., Ltd., Wellington, New Zealand

Tretjak, G. T., (Member), Electrotechnical Institute, Leningrad, Russia
Total 6

STUDENTS ENROLLED OCTOBER 14, 1925

Adey, Edwin A., Jr., Cornell University
Aikman, R. P., Kansas State Agricultural College
Alberga, Glenn H., Cornell University
Alworth, Cecil D., University of Oklahoma
Alworth, Thomas J., University of Oklahoma
Bauschman, Roland T., Cornell University
Beardslee, Robert W., West Virginia University
Beavers, Martin F., Alabama Polytechnic Institute
Best, Ralph W., Lehigh University
Boyden, Elwin C., Northeastern University
Brentnall, Elbert L., Montana State College
Brick, Joseph D., Cornell University
Carroll, William L., Mass. Institute of Technology
Carter, Harold B., Kansas State Agricultural College
Covington, Henry H., Jr., Virginia Military Institute
Cramer, Theron A., Bucknell University
Devine, Bernard A., University of Santa Clara
Dew, Philip H., Virginia Polytechnic Institute
Dixon, Fred C., Bucknell University
Durbeck, Edw. F., Jr., University of Oklahoma
Eakin, John W., University of Tennessee
Edson, Carl R., Northeastern University
Ellis, Samuel D., Jr., Rice Institute
Grabau, Francis W., Northeastern University
Gray, Walter M., Northeastern University
Hafer, Luther S., Lafayette College
Harder, Edwin L., Cornell University
Harrison, James A., University of Santa Clara
Hartsfield, James M., Jr., Rice Institute
Hermon, Ralph, Kansas State Agricultural College
Hixon, Willard M., Kansas State Agricultural College
Holbird, James R., University of Oklahoma
Howdeshell, Allen, D., Texas A. & M. College
Hufeisen, J. Laurence, University of Santa Clara
Huff, John F., Kansas State Agricultural College
Hunt, Lendon, University of Oklahoma
Hunter, M. Irwin, Cornell University
Johnson, J. O., Kansas State Agricultural College
Keiper, Phillip C., University of Oklahoma
Kerns, Albert H., Kansas State Agricultural College
Krummel, Robert L., Mass. Institute of Technology
Lawyer, Nevin D., Johns Hopkins University
Locher, Howard H., Purdue University
Lundy, Curtis S., South Dakota State College of A. & M. Arts
MaCarthy, Norman F., Northeastern University
MacCarthy, Donnell D., Cornell University
Martz, James V., Bucknell University
Miller, Carl G., Cornell University
Miller, Carl H., Kansas State Agricultural College
Miller, Charles W., Northeastern University
Miller, Horace G., Kansas State Agricultural College
Miramontes, Frank C., University of Santa Clara
Moore, Samuel E., Virginia Polytechnic Institute
Morganstern, Richard R., Cornell University
Murphy, James F., Kansas State Agricultural College
Nelson, C. Wesley, Northeastern University
Norton, Fred L., University of Tennessee
Odell, Norman S., Cornell University
Ortega, M., Rolfo, Escuela Ingenieros Mecanicos y Electricistas
Owens, Richard M., Harvard University
Rex, Earle C., University of Notre Dame
Roess, Louis C., Cornell University
Rose, Eugene E., Jr., Cornell University
Schurr, Frederick F., Cornell University
Schwarze, Karl A., University of Santa Clara
Seifkin, Ernest R., Kansas State Agricultural College
Shaw, Frank W., Kansas State Agricultural College
Shepherd, Paul A., Kansas State Agricultural College
Shults, John E., Cornell University
Sloan, Clarence A., Kansas State Agricultural College
Smith, Clarence W., Northeastern University
Speck, John K., University of Oklahoma
Sproul, H. Web, Kansas State Agricultural College
Steiger, Benjamin F., Cornell University
Stevens, Clarence R., University of Oklahoma
Teixeira, George, University of Santa Clara
Ten Broeck, Robert L., Lafayette College
Theberge, Albert R., Northeastern University
Tosi, Alexander A., University of Santa Clara
Van Noy, Thomas A., Montana State College
Vasconcellos, John B., University of Santa Clara
Volkel, Forrest B., Kansas State Agricultural College
Vukota, John E., University of Santa Clara
Widdowfield, William C., Lehigh University
Winter, H. LaMont, Bucknell University
Wood, Frederick L., Brown University
Woodman, Lawrence E., Kansas State Agricultural College
Yost, John, Kansas State Agricultural College
Total 88

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A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons Ltd., 24 Bruce Road, Bombay—1, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

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(A list of the personnel of Institute committees may be found in the September issue of the JOURNAL.)

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ELECTROPHYSICS, J. H. Morecroft
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GENERAL POWER APPLICATIONS, A. M. MacCutcheon
POWER GENERATION, Vern E. Alden
POWER TRANSMISSION AND DISTRIBUTION, Percy H. Thomas
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U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION
WASHINGTON AWARD, COMMISSION OF

A. I. E. E. SECTIONS AND BRANCHES

See the September issue for the latest published list. The Institute now has 49 Sections and 81 Branches.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Parkway Cable.—Bulletin, 24 pp. Describes steel taped parkway cable, and illustrates many of its applications. The Okonite Company, Passaic, N. J.

Recording Pyrometers.—Bulletin 1-13, 12 pp. Describes Brown new design recording pyrometers. The Brown Instrument Company, Wayne & Windrim Aves., Philadelphia, Pa.

Transformer .—Bulletin 2048, 12 pp., gives Pittsburgh polyphase transformer test connection diagrams. Pittsburgh Transformer Company, Pittsburgh, Pa.

Blower Fans.—Bulletin 6103, 32 pp. Describes "American" high speed fans for direct-connected motor drive. American Blower Company, Detroit, Mich.

Motors.—Bulletin 4000, 16 pp. Describes "Reliance" a-c. and d-c. ball and roller bearing motors. Reliance Electric & Engineering Company, 1042 Ivanhoe Road, Cleveland, O.

Combination Testing Instrument.—Folder describes the "Avo" tester, a small pocket size instrument,—combination ammeter, voltmeter and ohmmeter. Electrical Engineering Service, 15 Park Row, New York.

Adjustable Lighting Fixtures.—Catalog 36, 20 pp. Describes "White" adjustable electric light fixtures for industrial, office and home use. O. C. White Company, Worcester, Mass.

Bus Supports.—Bulletin 31-B, 48 pp. Describes and illustrates a complete line of high tension bus supports, giving detailed dimensions of supports up to and including 120 kv. Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, Ill.

Welding Rods.—Booklet, 28 pp. Describes the properties of iron and steel filler rods for both gas and electric welding, and contains much other information regarding welding practise. Chicago Steel & Wire Company, 103rd Street & Torrence Avenue, Chicago, Ill.

Motion Recorders.—Catalog 1600, 20 pp. Describes Bristol mechanical motion and electrical operation recorders, for automatically recording actual operation, time of operation and the extent of mechanical movement. These instruments have a wide range of application, including operations of machinery, elevators, hoists, conveyors, opening and closing of doors, gates, valves, etc. The recorders may be used in connection with the Bristol long distance transmitting system, to transmit the records from the source of operation to a distant location of even several miles, as in the case of sluice gates for turbines. The Bristol Company, Waterbury, Conn.

NOTES OF THE INDUSTRY

The Johns-Pratt Company, Hartford, Conn., has removed its New York office to 20 Vesey Street.

Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, has issued a net price list on standardized outdoor substations. These prices took effect October 15 and will remain in force until March 15, 1926.

The Crocker-Wheeler Company, Ampere, N. J., announces a change in the company name effective November 1, 1925. The new name of the company will be Crocker-Wheeler Electric Manufacturing Company.

The General Electric Company, has received orders for the three months ending September 30 amounting to $73,561,483, compared with $58,389,832 for the same quarter in 1924, an increase of 26 per cent. For the nine months of the present year, orders total $223,876,711, compared with $203,097,719 for the first nine months of 1924, an increase of 10 per cent.

Standard Steel & Bearings, Inc., Plainville, Conn., announces a new line of ball bearings manufactured from molybdenum steel. Tests which the company has conducted over a long period indicate that the molybdenum steel balls possess a number of advantages over those of chrome alloy steel, including increased toughness and breaking strength, greater and more uniform hardness and extraordinary load carrying capacity.

The Westinghouse Electric & Manufacturing Company has received an order from the Brooklyn Edison Company for a steam condenser to be operated in conjunction with a 115,000 h. p. generating unit, larger than any other single unit heretofore constructed. The condenser and turbine equipment will be made at the South Philadelphia plant, while the generator will be delivered from the East Pittsburgh Works, the whole installation calling for an outlay of more than one and one-quarter million dollars. All the equipment is to be delivered at the Power Plant in Brooklyn early next Spring.

The Imperial Molded Products Corporation, Chicago, has been organized to engage in the manufacture of molded bakelite for the automotive, electrical and other industries using this product. The new company is controlled and financed by the Imperial Brass Manufacturing Company. The officers include Paul Tietz, president, James T. Greenlee, secretary and Frank McNellis, treasurer.

The Holtzer-Cabot Electric Company, Boston, Mass., has issued a handsomely printed and illustrated pamphlet entitled "Fifty Years," published in commemoration of the fiftieth anniversary of the company. The publication gives the history of the organization, and includes many photographs of the Company's operating personnel. Charles William Holtzer, president and founder of the company, has been an Associate of the A. I. E. E. since 1901.

The Robert June Engineering Management Organization, Detroit, has acquired control of the Electric Flow Meter Company at Kansas City, Mo., formerly the Hyperbo-Electric Flow Meter Company of Chicago, and will henceforth operate the business under its own management with executive offices at 8835 Linwood Avenue, Detroit, Michigan. Robert June becomes president of the company, J. M. Naiman, formerly general manager, becomes vice-president, consulting and chief engineer, with Major W. W. Burden of the Robert June Organization as treasurer.

Westinghouse Promotions.—At a recent meeting of the directors of the Westinghouse Company, Edward D. Kilburn, vice-president and general manager of the Westinghouse Electric International Company, and Walter S. Rugg, general sales manager of the Westinghouse Electric & Manufacturing Company, were named vice-presidents of the latter company. Messrs. Rugg and Kilburn will take charge respectively of the engineering and sales activities. Mr. Kilburn, in addition to his new appointment will retain his duties as vice-president and general manager of the Westinghouse Electric International Company. Mr. Rugg has been identified with the company since 1892, and Mr. Kilburn since 1906. Vice-president H. P. Davis, formerly in charge of engineering and manufacturing activities as applying strictly to the electrical portions of the company's business, will have direction over the entire manufacturing activities of the company, and in addition will direct the radio business, including broadcasting.